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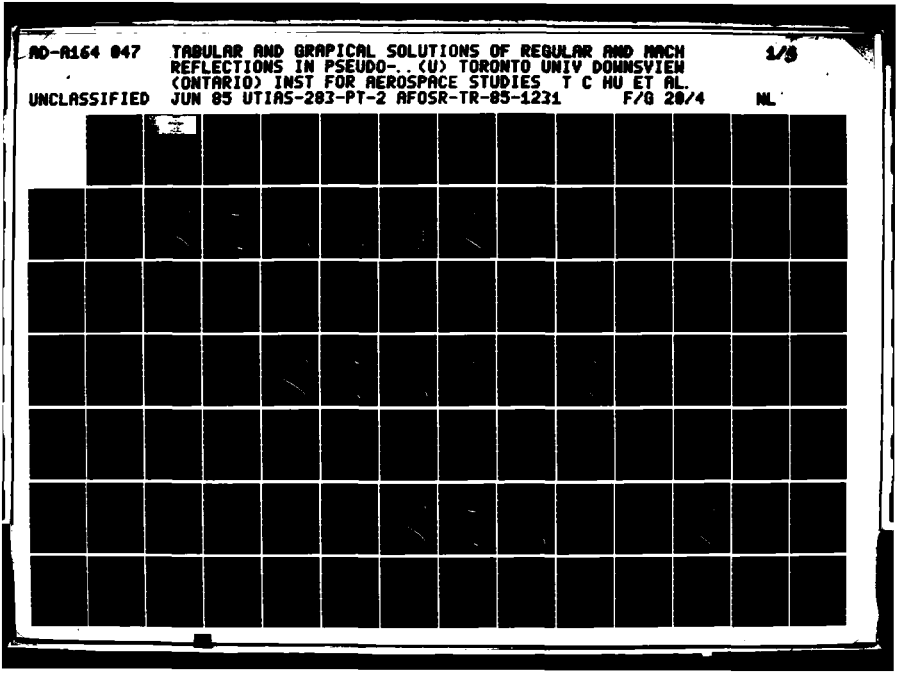

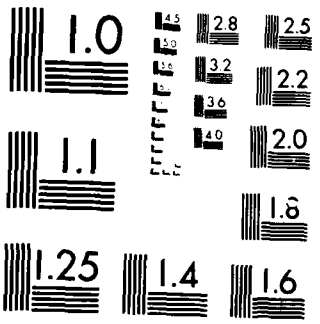

INSTITUTE
FOR
AEROSPACE STUDIES
UNIVERSITY OF TORONTO

TABULAR AND GRAPHICAL SOLUTIONS OF REGULAR AND MACH REFLECTIONS IN PSEUDO-STATIONARY FROZEN AND VIBRATIONAL-EQUILIBRIUM FLOWS

PART 2

by

T. C. J. Hu and M. Shirouzu

June 1985

UTIAS Report No. 283
CN ISSN 0082-5255

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A160 607

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): UTIAS Report No. 283 (in two parts)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- [illegible] 1 2 3
6a. NAME OF PERFORMING ORGANIZATION: University of Toronto, Inst. for Aerospace Studies; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: AFOSR/NA
6c. ADDRESS (City, State and ZIP Code): 4925 Dufferin Street, Downsview, Ontario, Canada M3H 5T6	7b. ADDRESS (City, State and ZIP Code): Building 410, Bolling AFB, DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Air Force Office of Scientific Research/NA; 8b. OFFICE SYMBOL (If applicable): AFOSR/NA	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: AF-AFOSR 82-0096
8c. ADDRESS (City, State and ZIP Code): Bldg. 410, Bolling Air Force Base, DC 20332, U.S.A.	10. SOURCE OF FUNDING NOS. — PROGRAM ELEMENT NO.: 61102F; PROJECT NO.: 2307; TASK NO.: A1; WORK UNIT NO.:
11. TITLE (Include Security Classification): Tabular and Graphical Solutions of Regular and Mach Reflections in Pseudo-Stationary Frozen and Vibrational-Equilibrium Flows, Part 2	
12. PERSONAL AUTHOR(S): T. C. J. Hu and M. Shirouzu	
13a. TYPE OF REPORT: Interim; 13b. TIME COVERED: FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day): 1985, June; 15. PAGE COUNT: 352
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Oblique-shock-wave reflections; regular reflection; Mach reflection; numerical and graphical solutions; frozen and equilibrium flows.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Flow properties of pseudo-stationary oblique-shock-wave reflections are given as solutions of two-shock and three-shock theories. The calculations were performed for Ar, air, CO_2 and SF_6 using both frozen and vibrational equilibrium gas assumptions. The flow properties are tabulated for initial shock Mach numbers $1.2 < M_s < 10.0$ and wedge angles $1° < \theta_w < 85°$. The flow properties are plotted as a function of the incident shock Mach number for a series of wedge angles for both regular and Mach reflections. Another set of graphs is presented for Mach reflection with the flow properties plotted against the effective wedge angle θ_w' for a series of shock Mach numbers. The latter set is used when the effective wedge angle is chosen as the parameter for comparison. The second triple-point system, which exists only in double-Mach reflection, is solved numerically for the first time, and the solutions are presented both in tabular and graphical forms. The tables and graphs are designed to serve the analyst and experimenter working on oblique-shock-wave reflections.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: JAMES D WILSON	22b. TELEPHONE NUMBER (Include Area Code): (202) 767-4935; 22c. OFFICE SYMBOL: AFOSR/NA

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

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Submitted October 1984

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UTIAS Report No. 283
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Notation

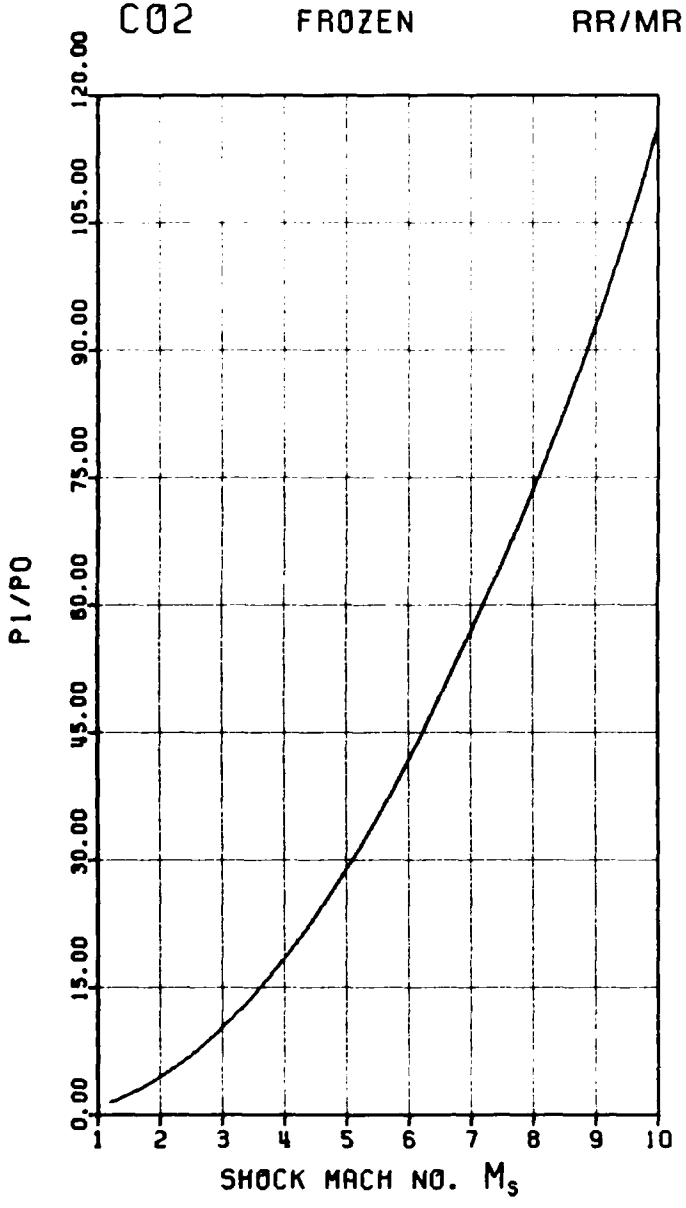
Notations used in tables are shown in parentheses.

a	sound speed (A)
Ar	argon
CO_2	carbon dioxide
h	specific enthalpy
K	kink
M	Mach number (relative to P or T unless otherwise indicated) (MACH)
m	molecular weight
MR	Mach reflection
M_s	incident shock Mach number (MACHS)
n_k	number of modes in mode k
N_2	nitrogen
O_2	oxygen
P	reflection point
p	pressure (P)
R	universal gas constant
RR	regular reflection
SF_6	sulphur hexafluoride
T	temperature
T	triple point
T'	second triple point
T_k	characteristic temperature of mode k
u	flow velocity
γ	specific heat ratio
γ_p	specific heat ratio of perfect gas
γ_o	specific heat ratio of frozen gas

δ	angle between incident shock wave and reflected shock wave at triple point (DELTA)
η	angle between reflected shock wave and second Mach stem (ETA)
θ	deflection angle of flow from its original direction while passing through a shock wave (THETA)
θ_w	actual wedge angle (THETA WALL)
θ'_w	effective wedge angle (THETA WALL PRIME)
ξ	angle between the two reflected shock waves R and R' in region (1) (XI)
ρ	density (RHO)
ϕ	incident wave angle (PHI)
χ	triple-point-trajectory angle (CHI)
χ'	second-triple-point-trajectory angle (CHI PRIME)
ω'	angle between reflected shock wave and wedge surface (in RR) or triple-point-trajectory (in MR) (OMEGA PRIME)

Subscripts

0, 1, 2, 3	regions 0, 1, 2, 3 (0, 1, 2, 3)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P1/P0
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1 2 3 4 5 6 7 8 9 10
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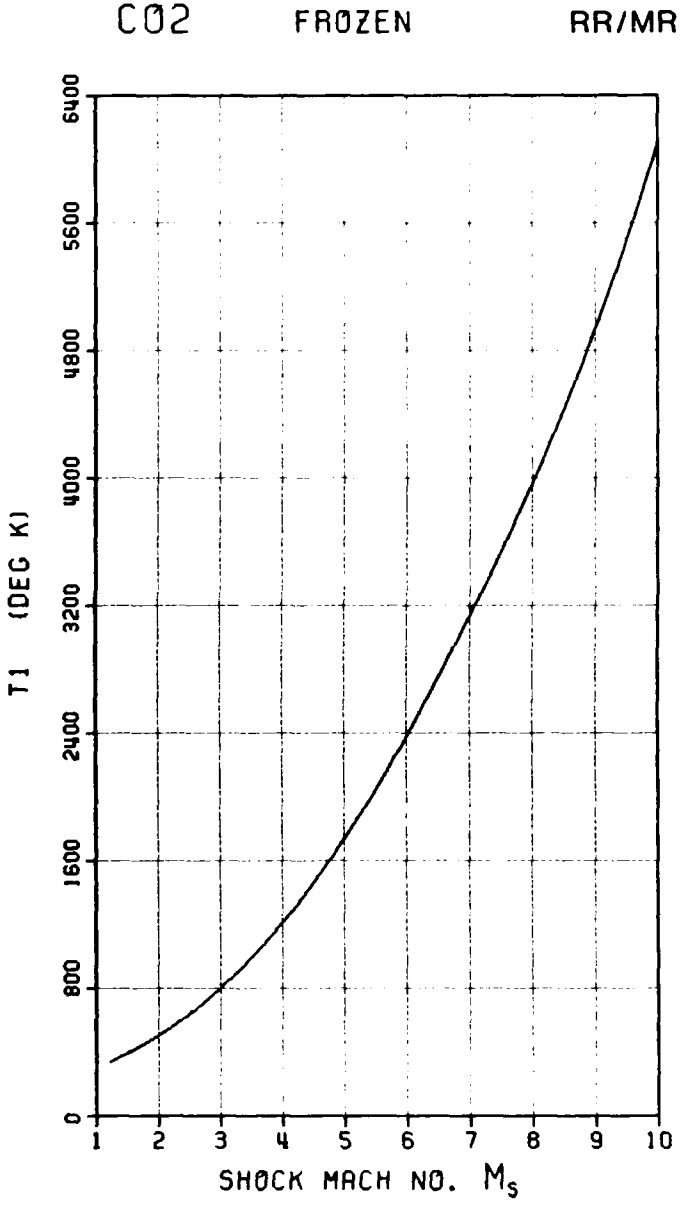
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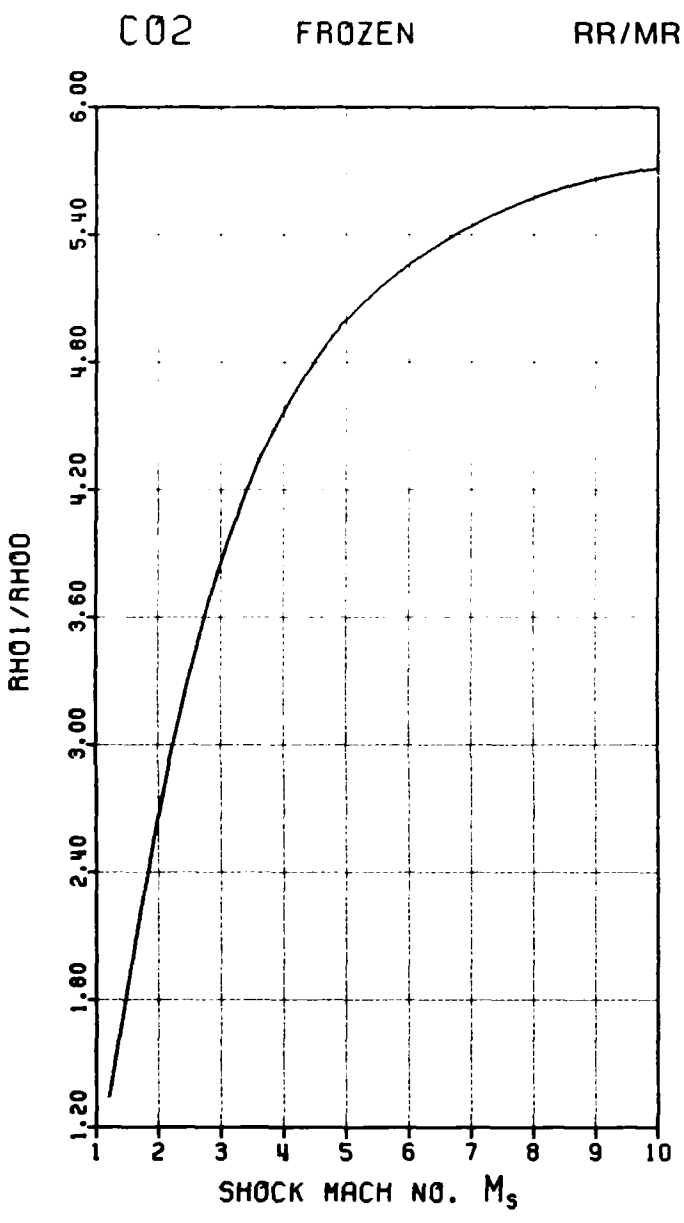
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1.80
1.20
1 2 3 4 5 6 7 8 9 10
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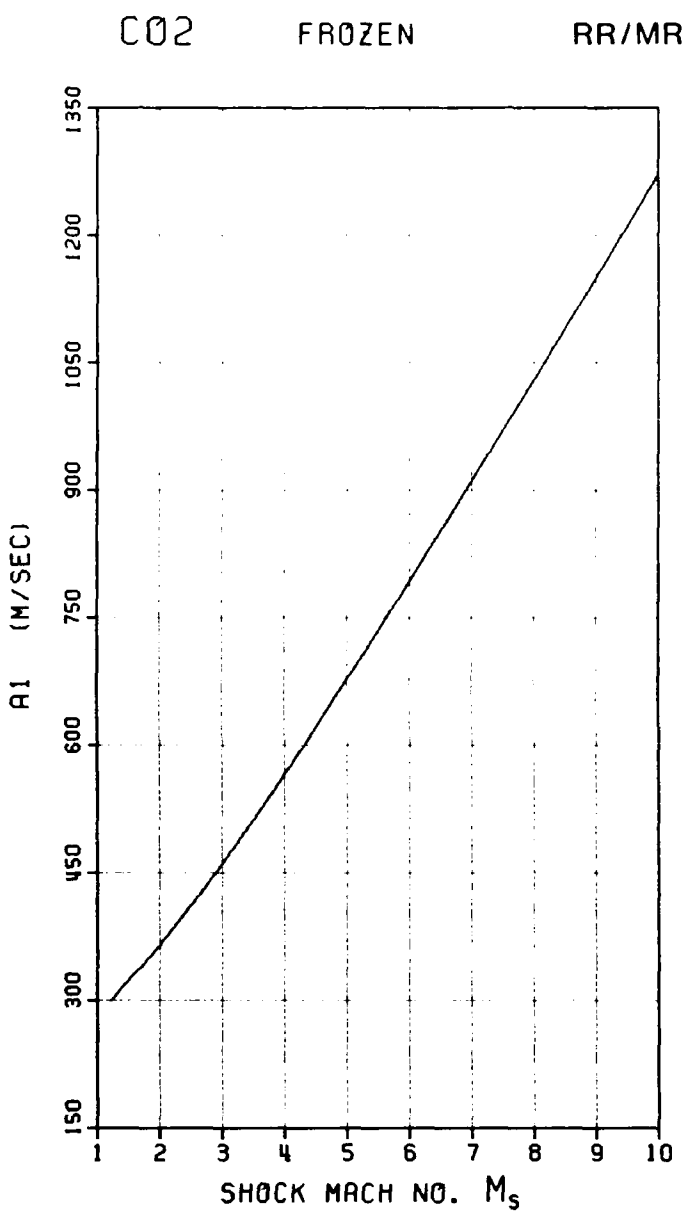
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900
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600
450
300
150
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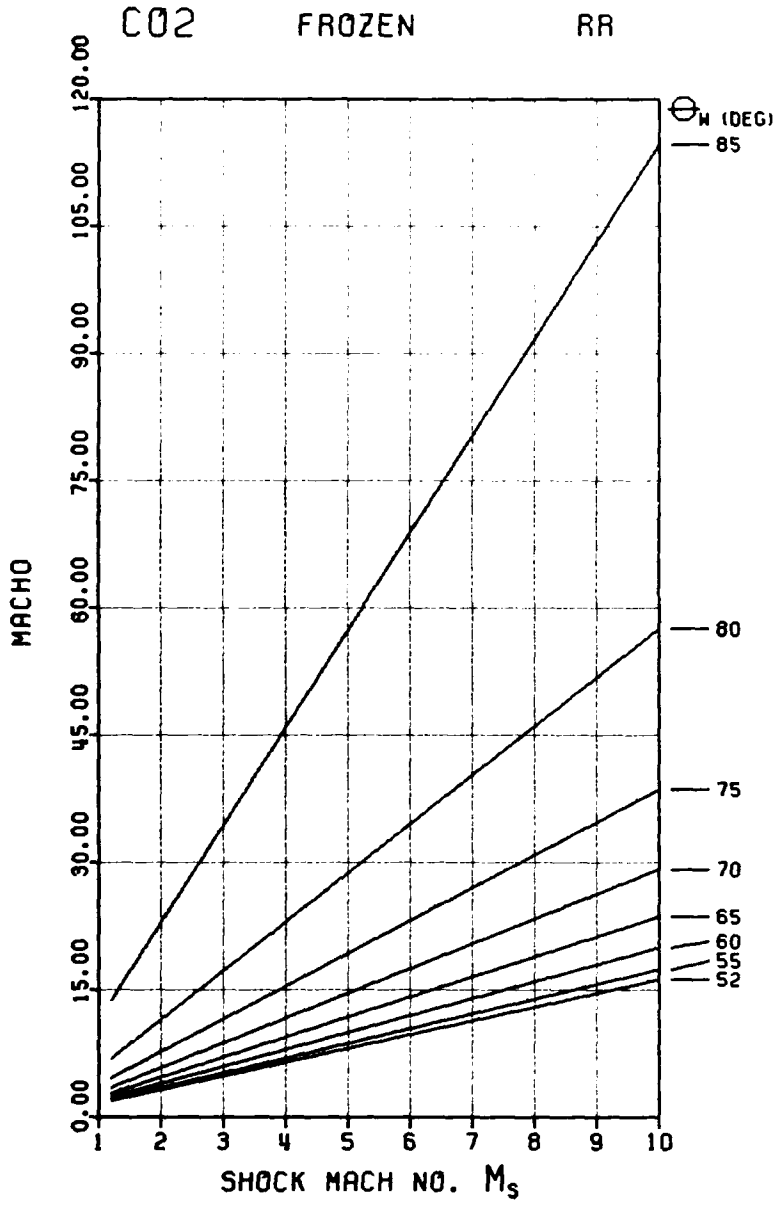
SHOCK MACH NO. M_S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MACH0
SHOCK MACH NO. M_S
θ_W (DEG)
85
80
75
70
65
60
55
52
0.00
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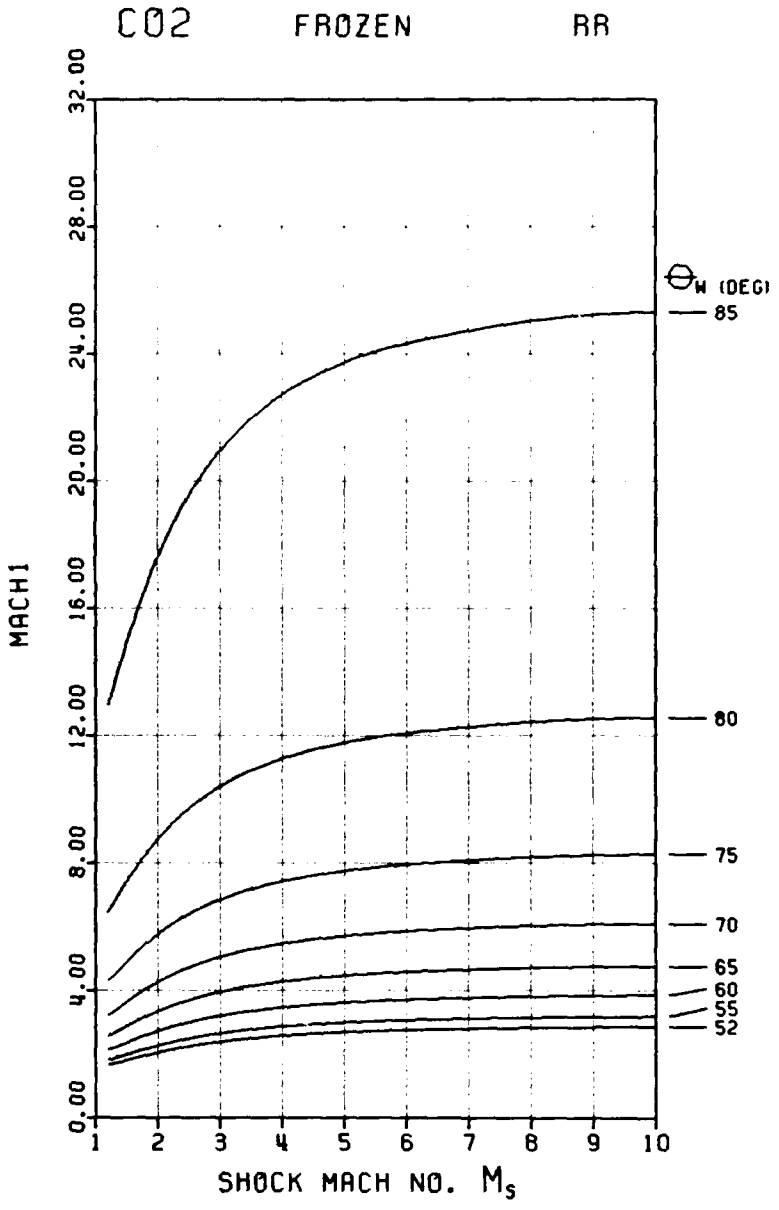
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1 2 3 4 5 6 7 8 9 10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MACH1
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80
75
70
65
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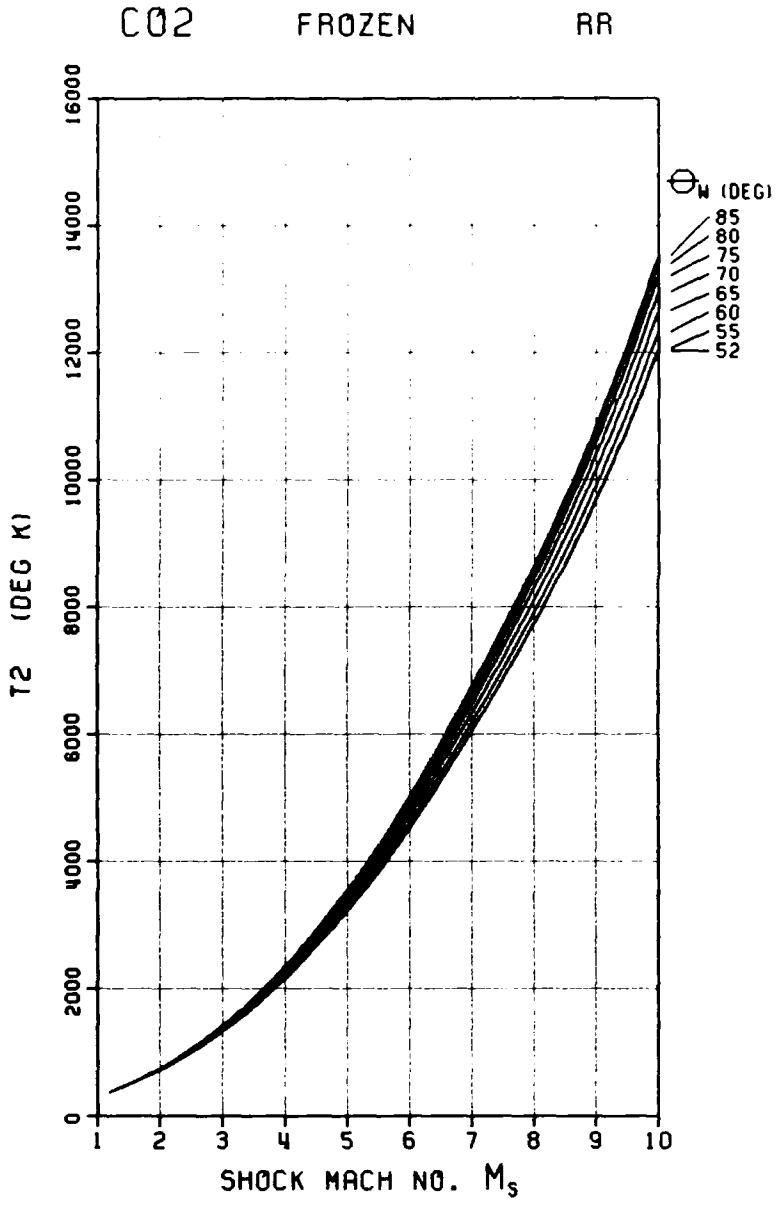
16.00
20.00
24.00
28.00
32.00
1 2 3 4 5 6 7 8 9 10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T2 (DEG K)
0
2000
4000
6000
8000
10000
12000
14000
16000
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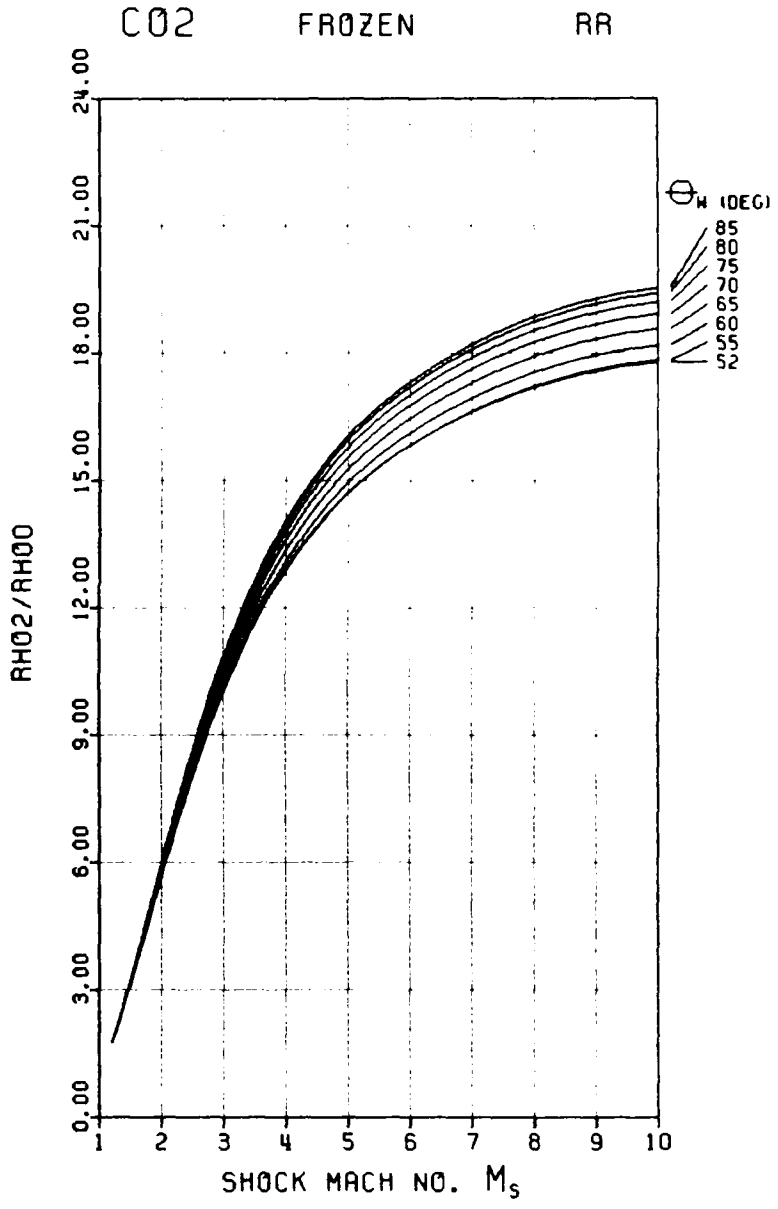
Θ_W (DEG)
85
80
75
70
65
60
55
52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RH02/RH00
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3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
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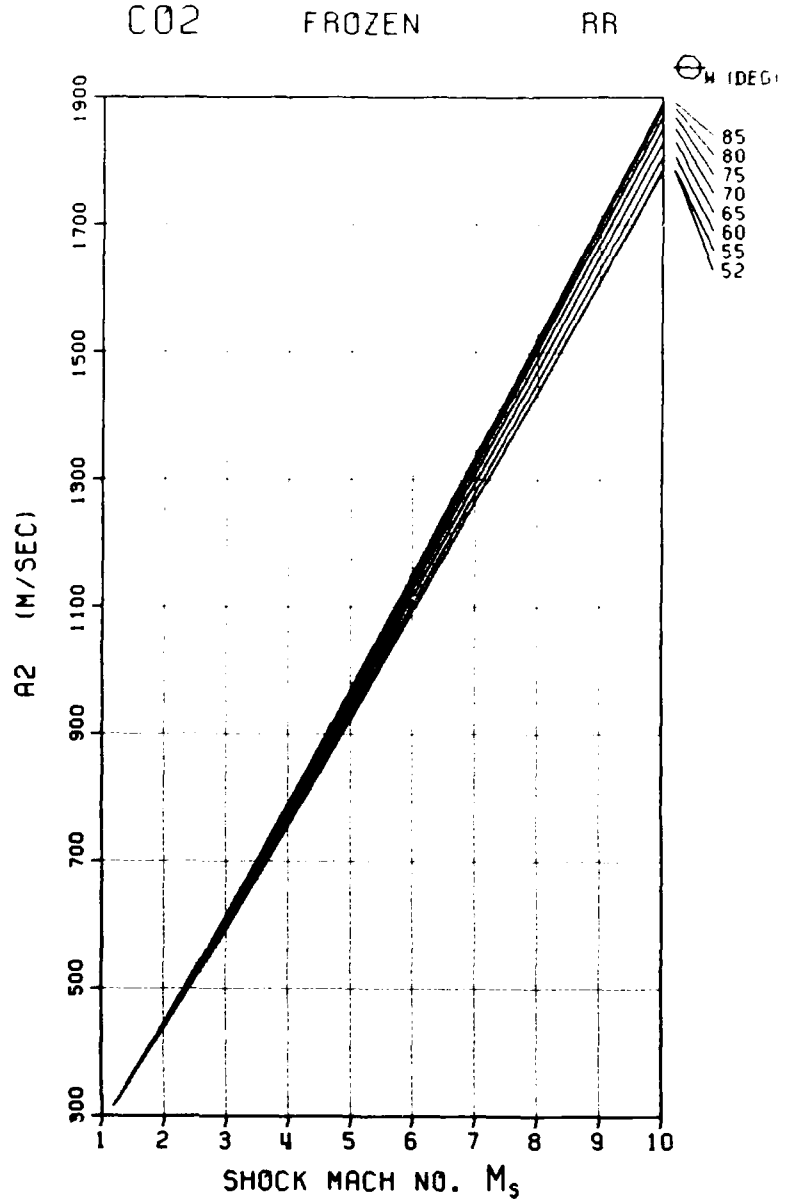
Θ_W (DEG)
85
80
75
70
65
60
55
52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80
75
70
65
60
55
52
A2 (M/SEC)
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500
700
900
1100
1300
1500
1700
1900
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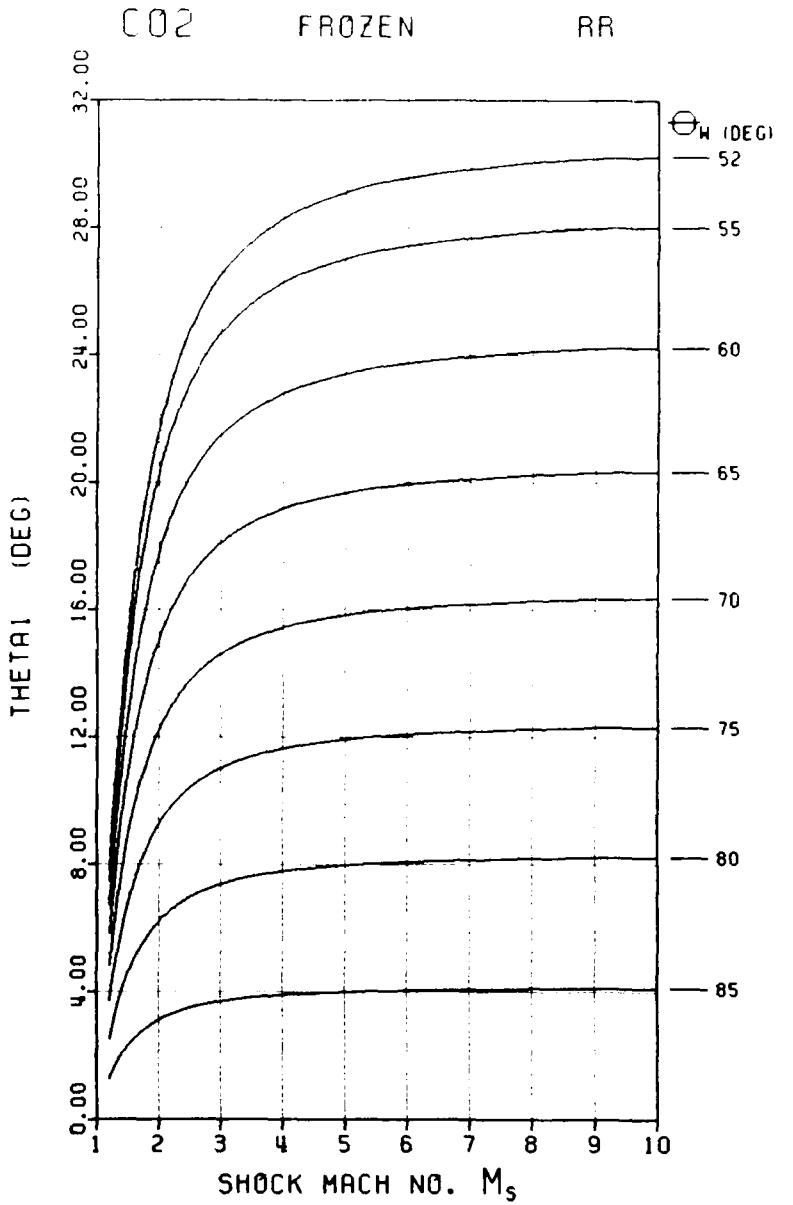
SHOCK MACH NO. M_S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60
65
70
75
80
85
THETA1 (DEG)
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16.00
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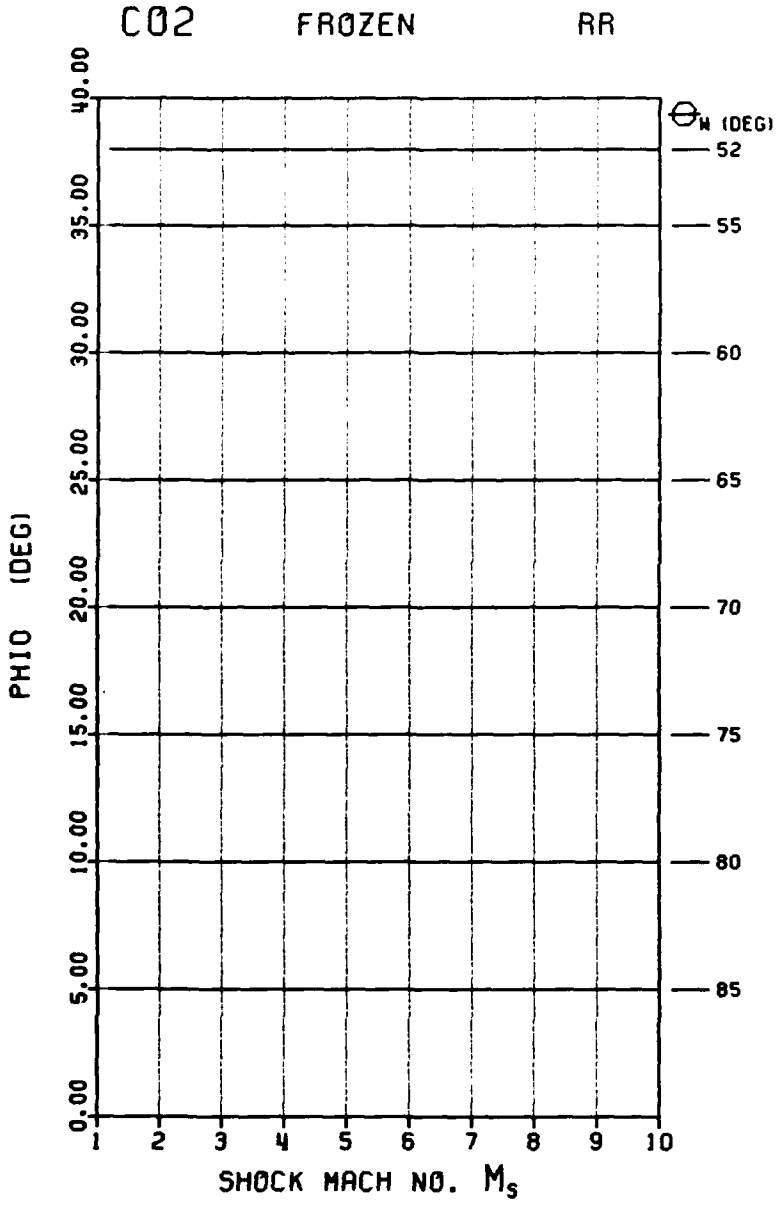
28.00
32.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S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PHI0 (DEG)
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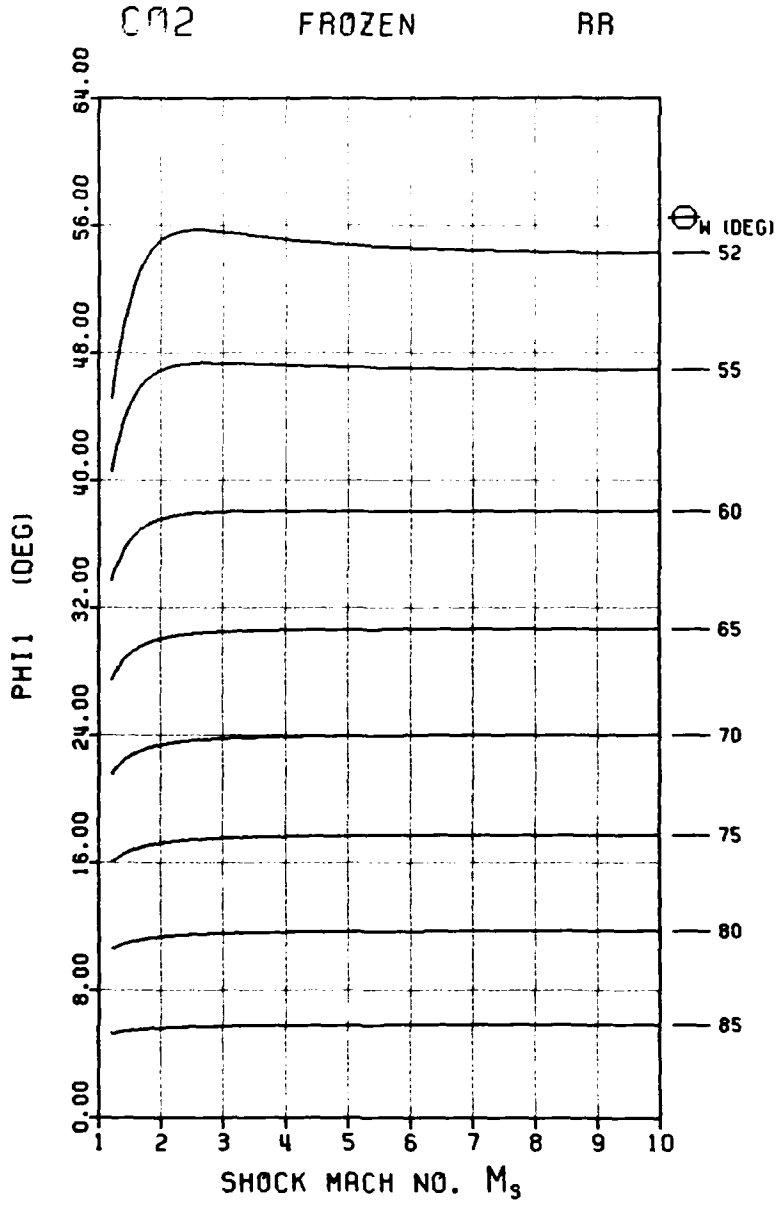
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
52
55
60
65
70
75
80
85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8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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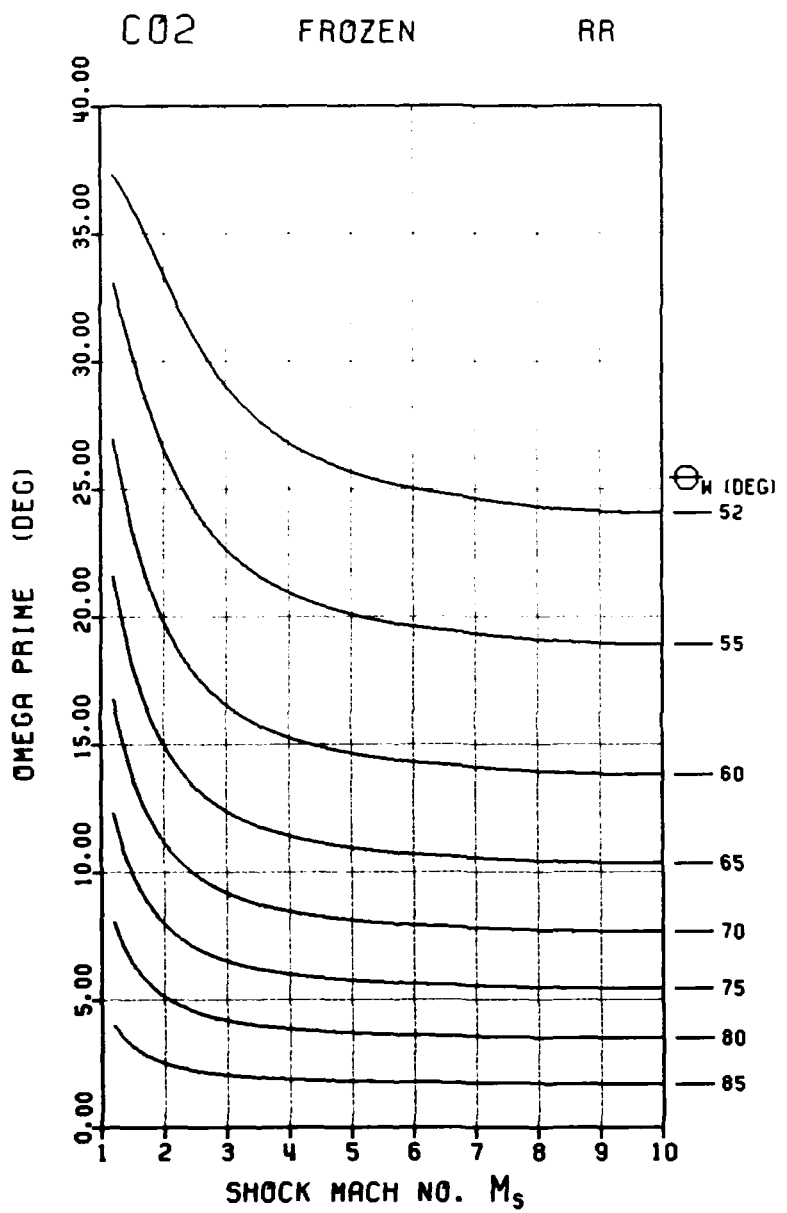
55
60
65
70
75
80
85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15.00
20.00
25.00
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40.00
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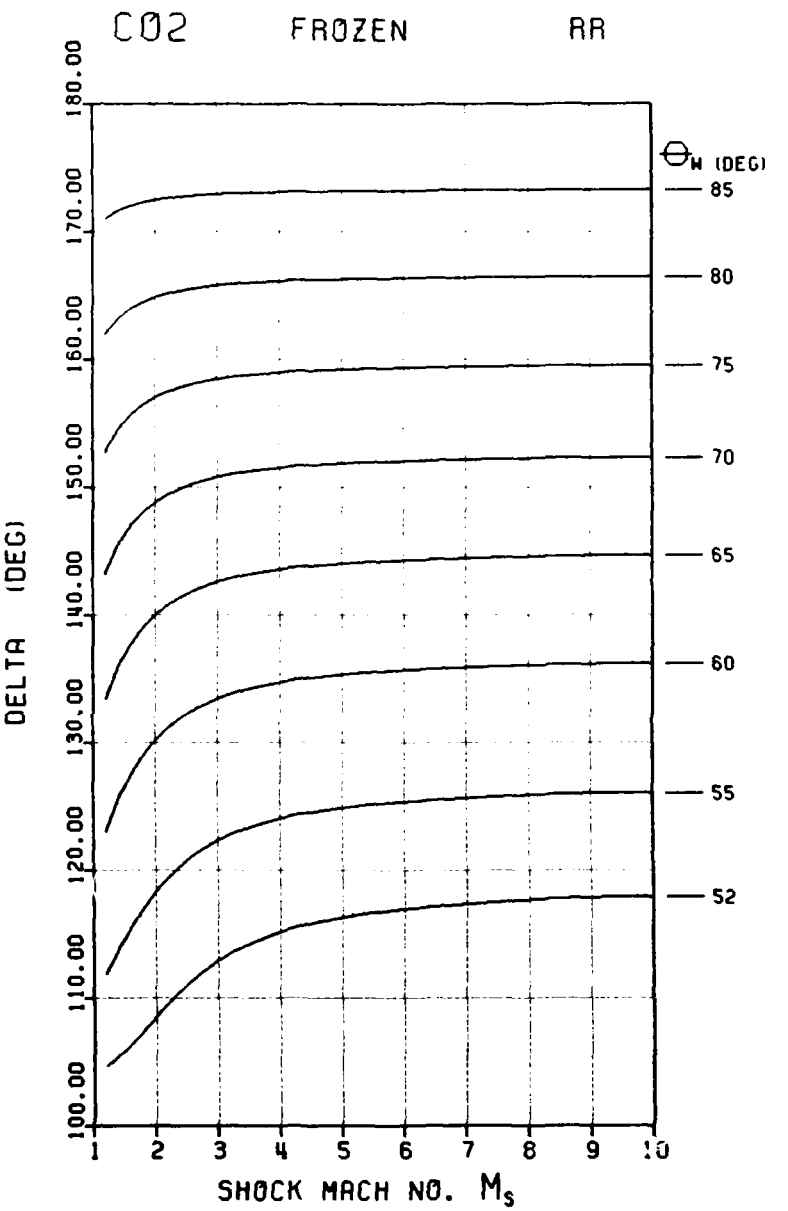
Θ_W (DEG)
52
55
60
65
70
75
80
85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160.00
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180.00
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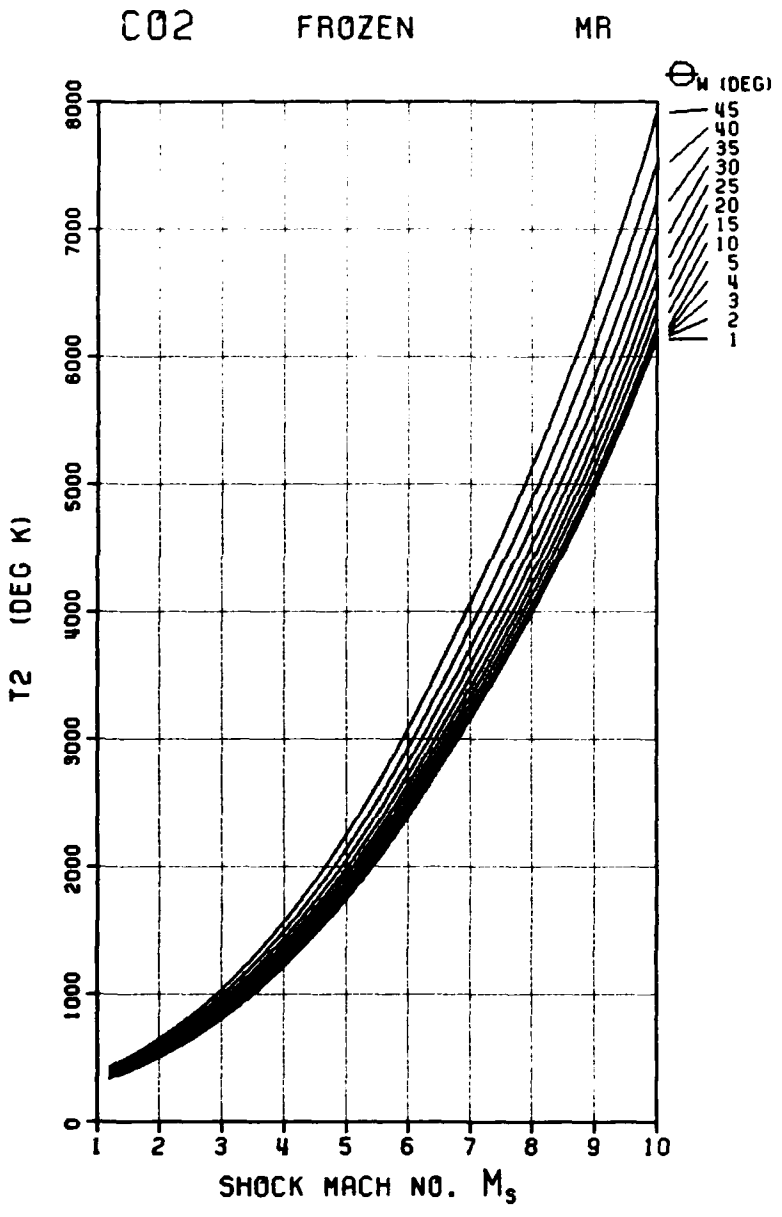
80
75
70
65
60
55
52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40
35
30
25
20
15
10
5
4
3
2
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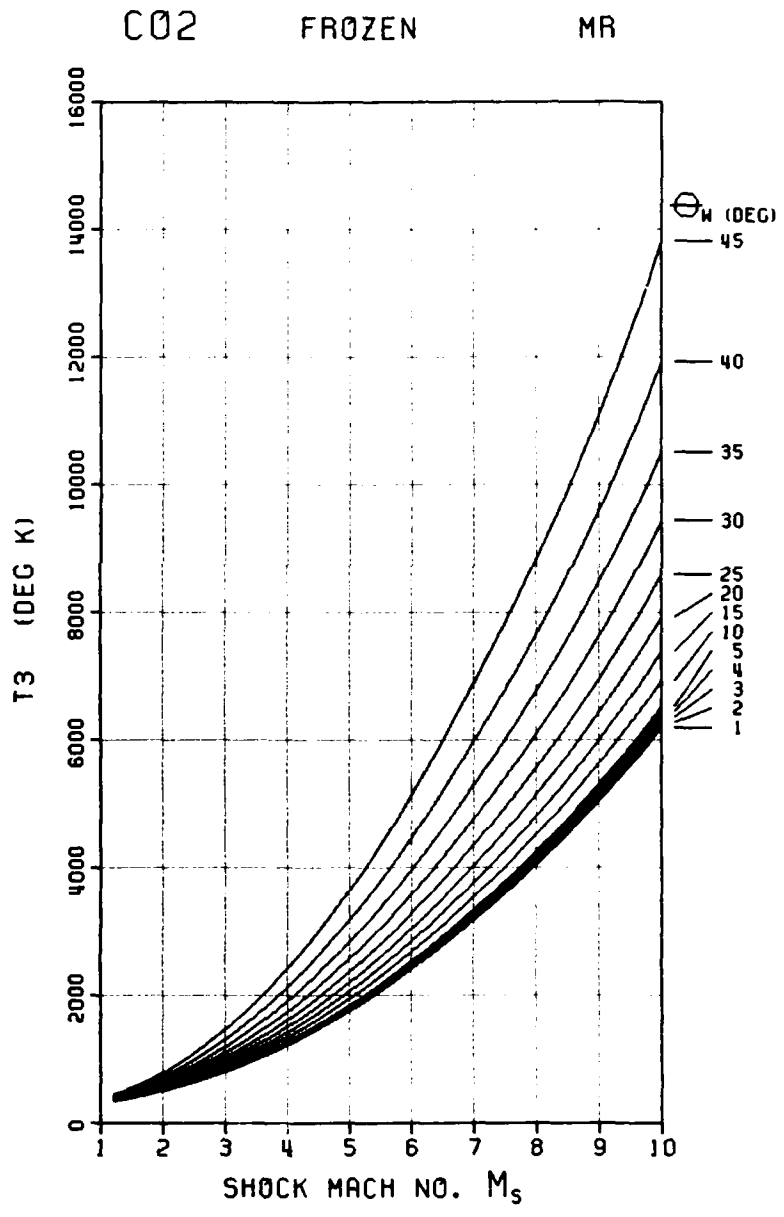
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35
30
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4
3
2
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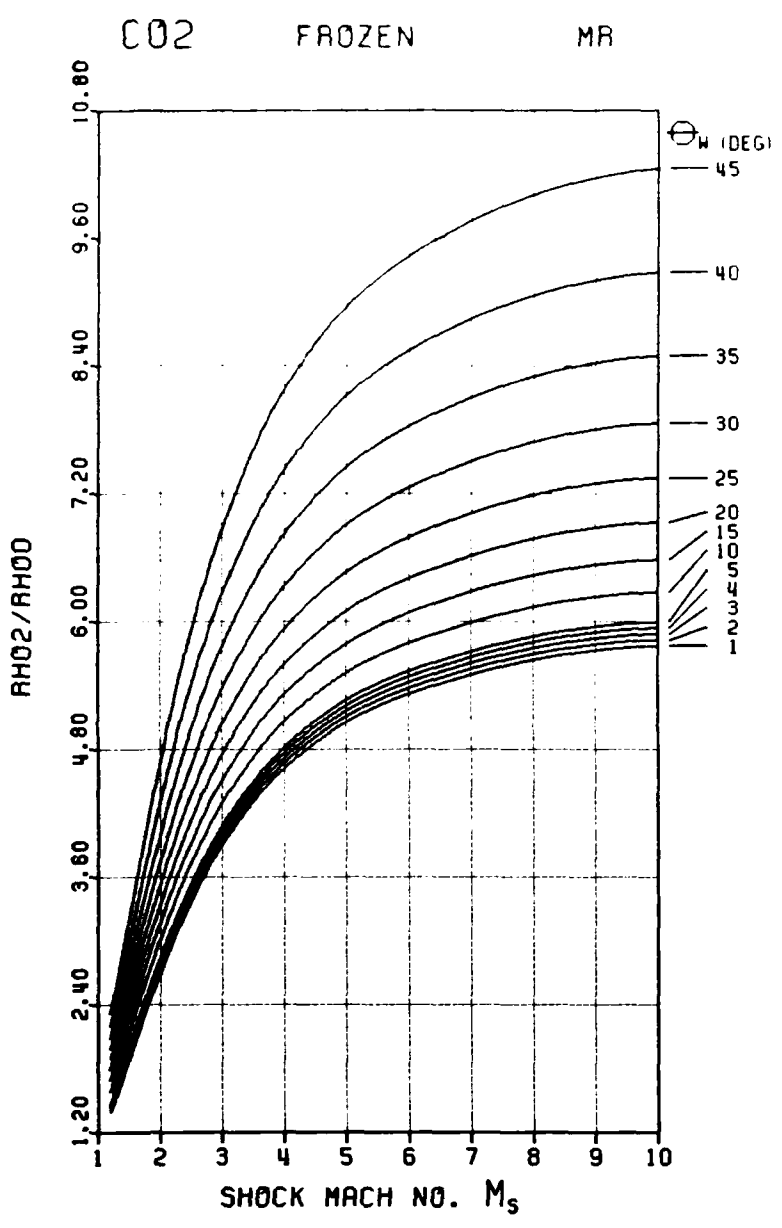
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35
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10
5
4
3
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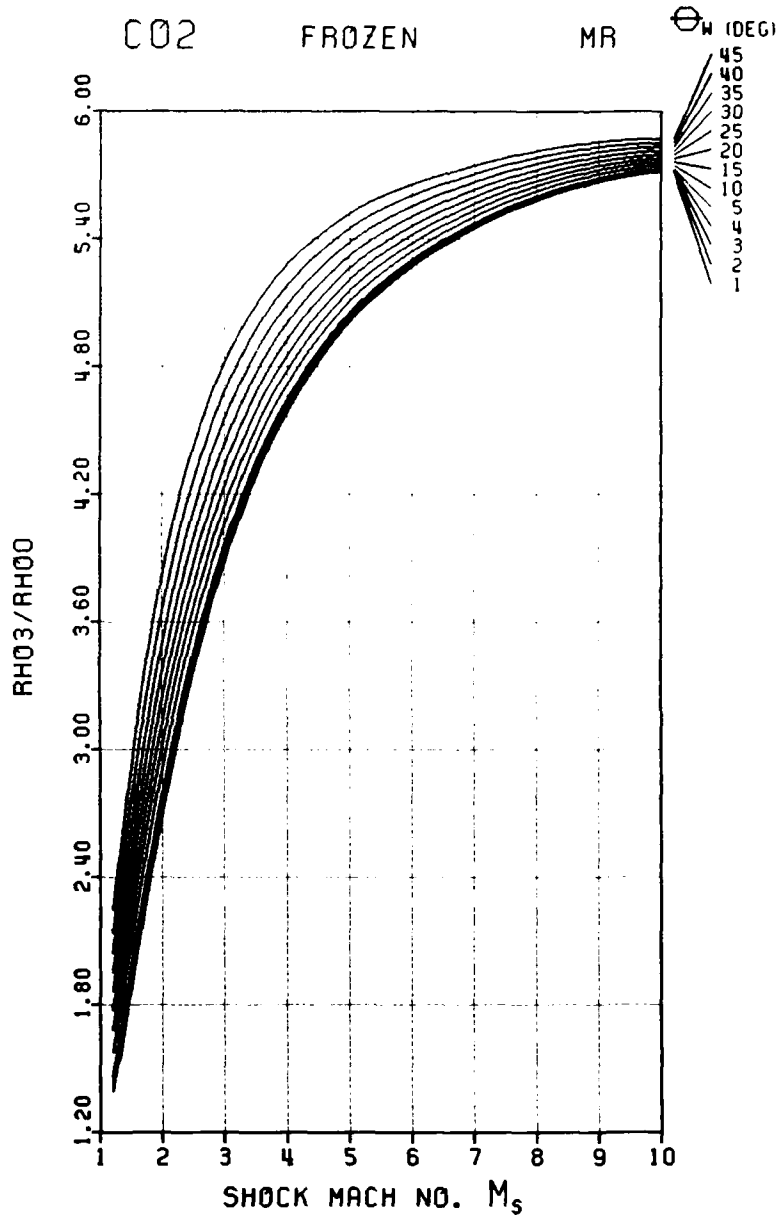
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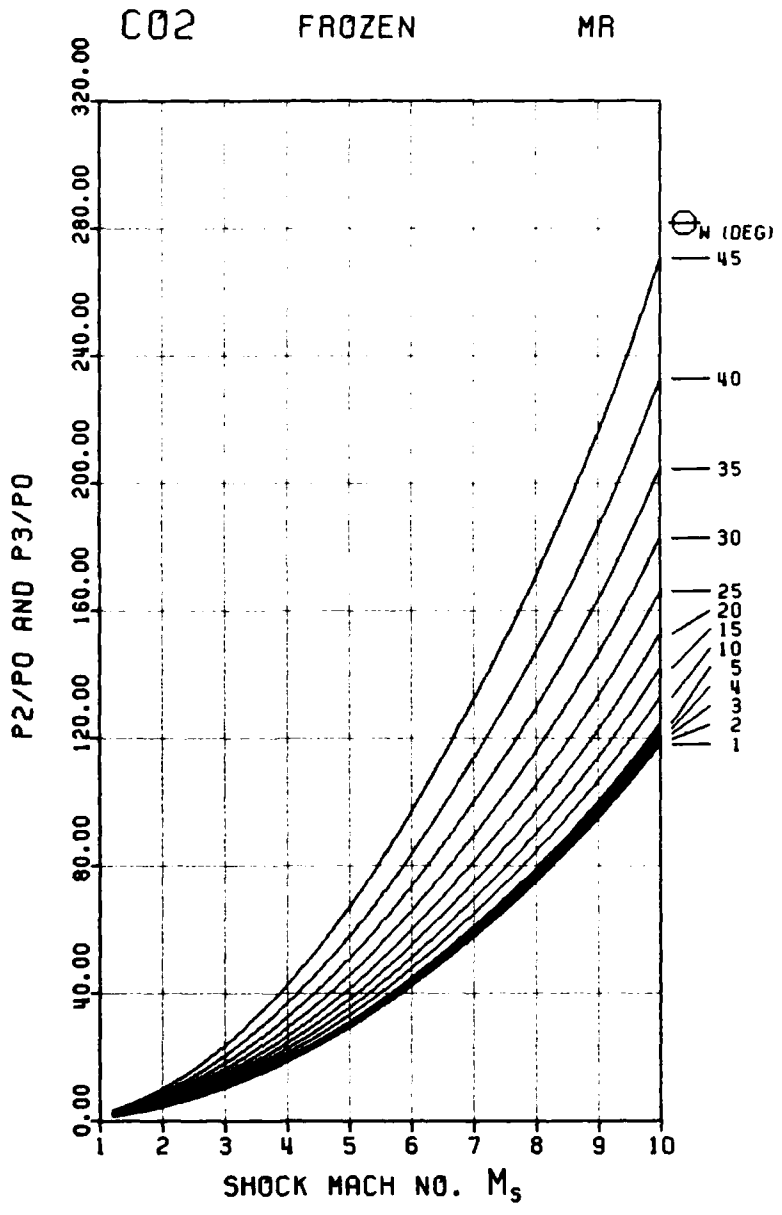
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320.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
θ_W (DEG)
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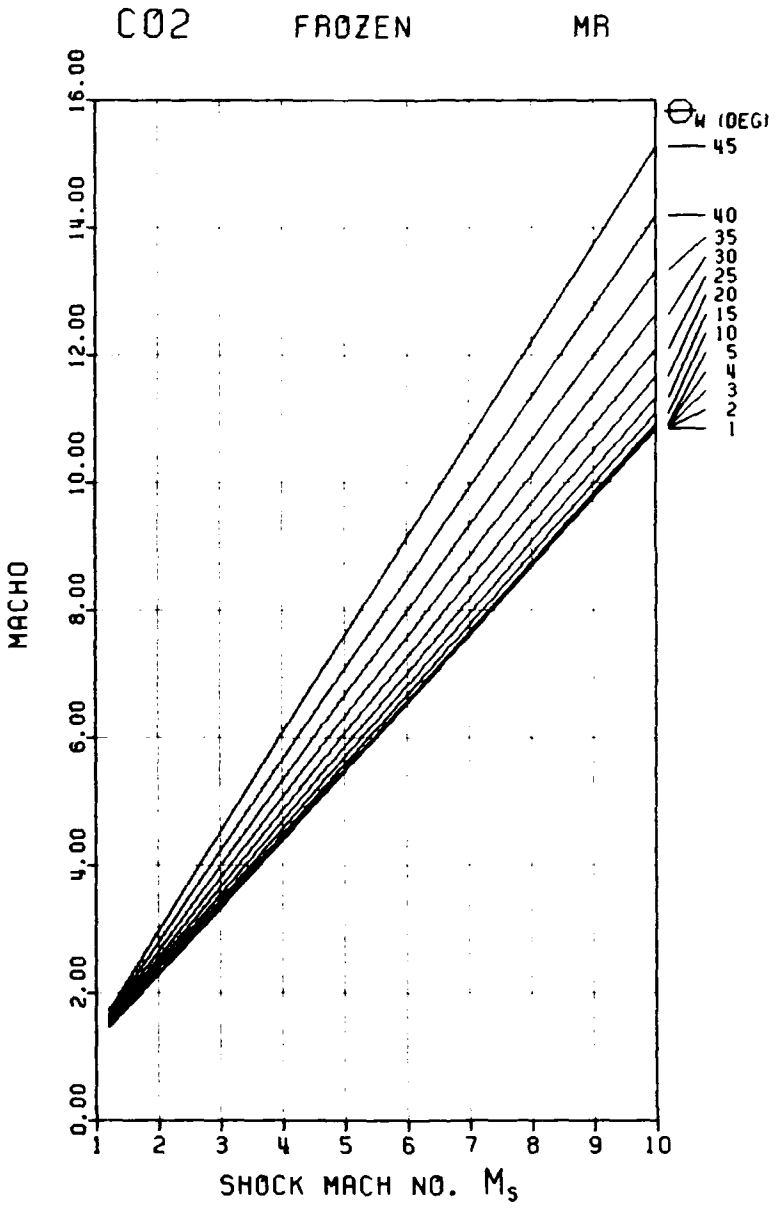
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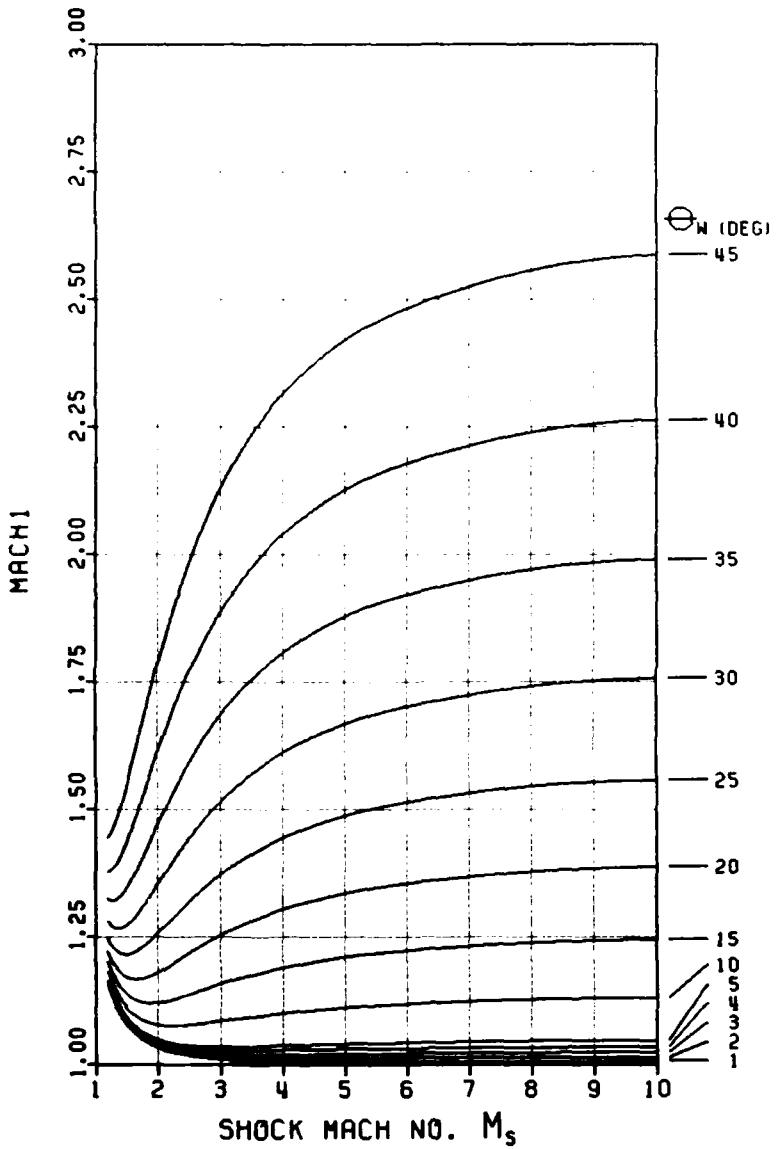
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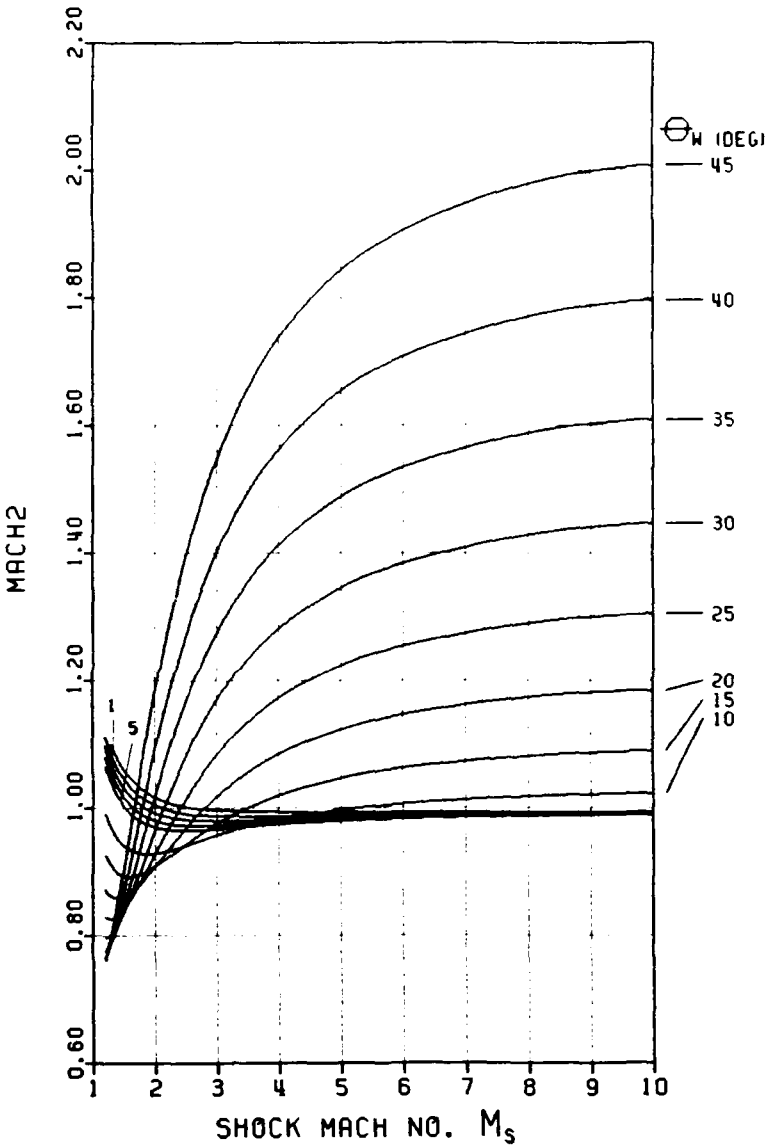
2
1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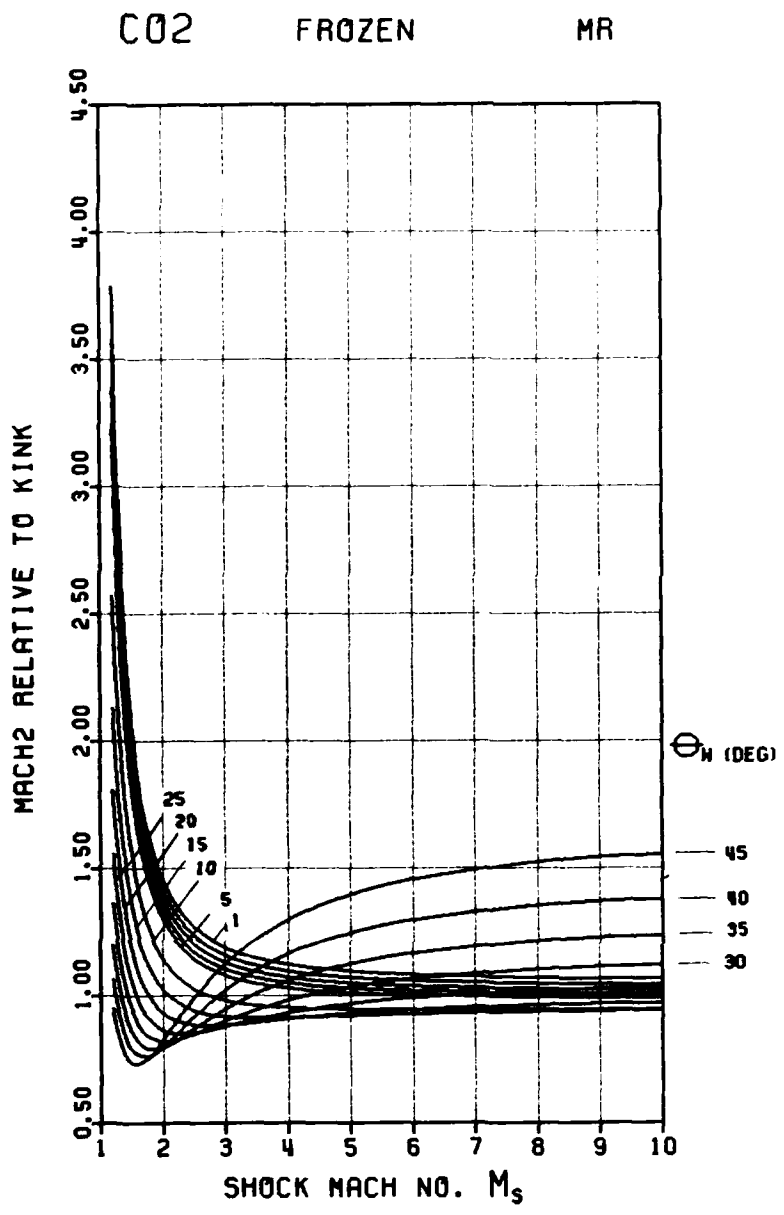
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40
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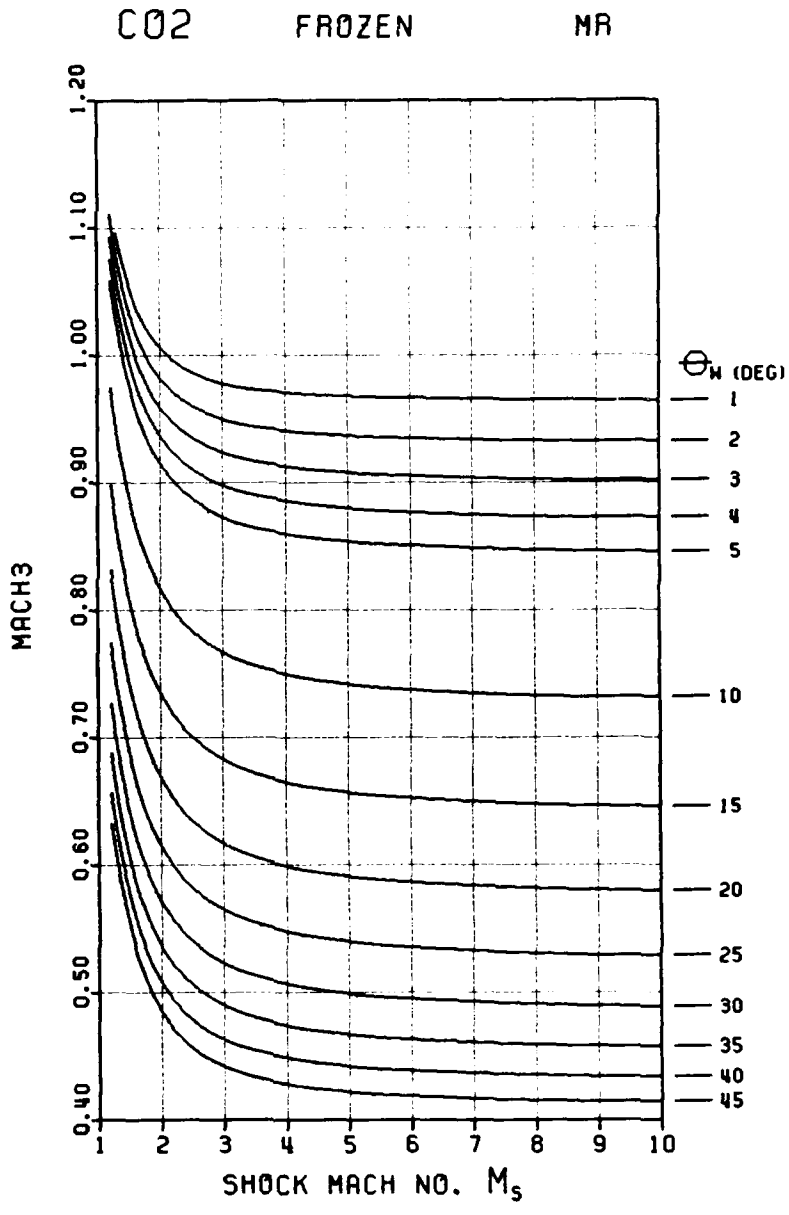
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MACH3
SHOCK MACH NO. M_S
Θ_W (DEG)
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2
3
4
5
10
15
20
25
30
35
40
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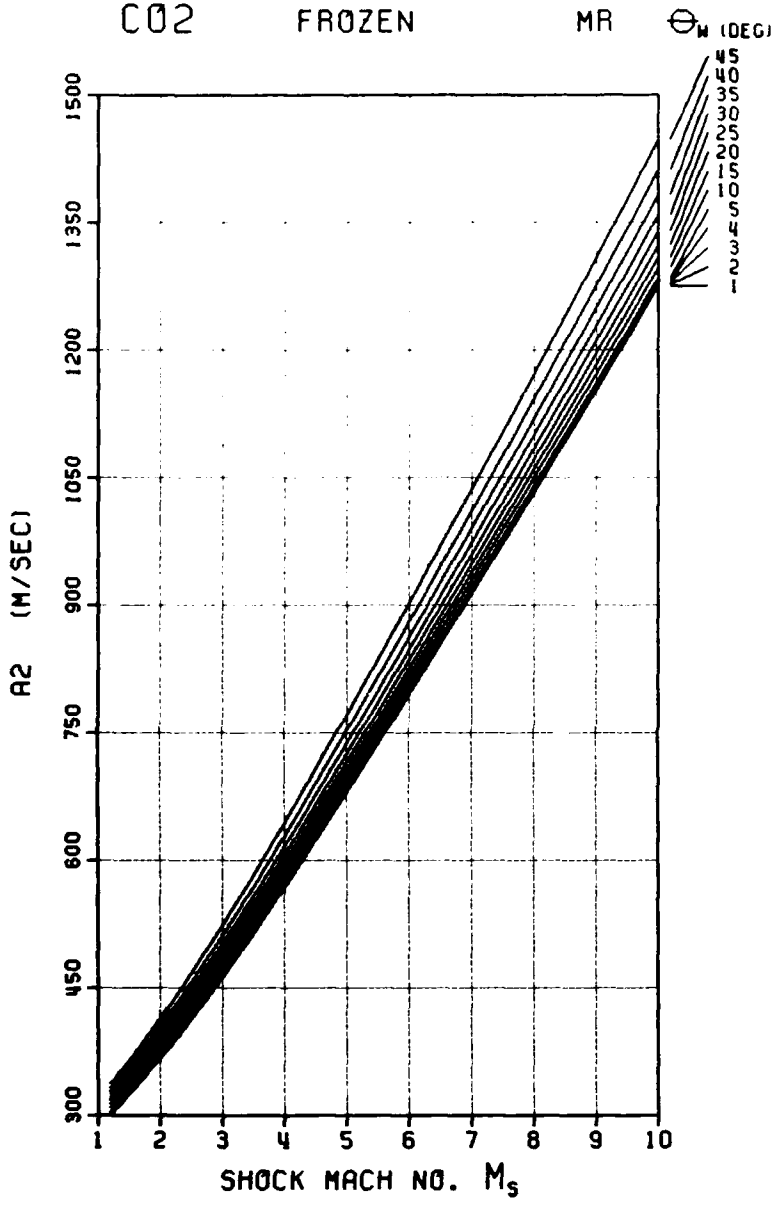
CO2 FROZEN MR
Θ_W (DEG)
45
40
35
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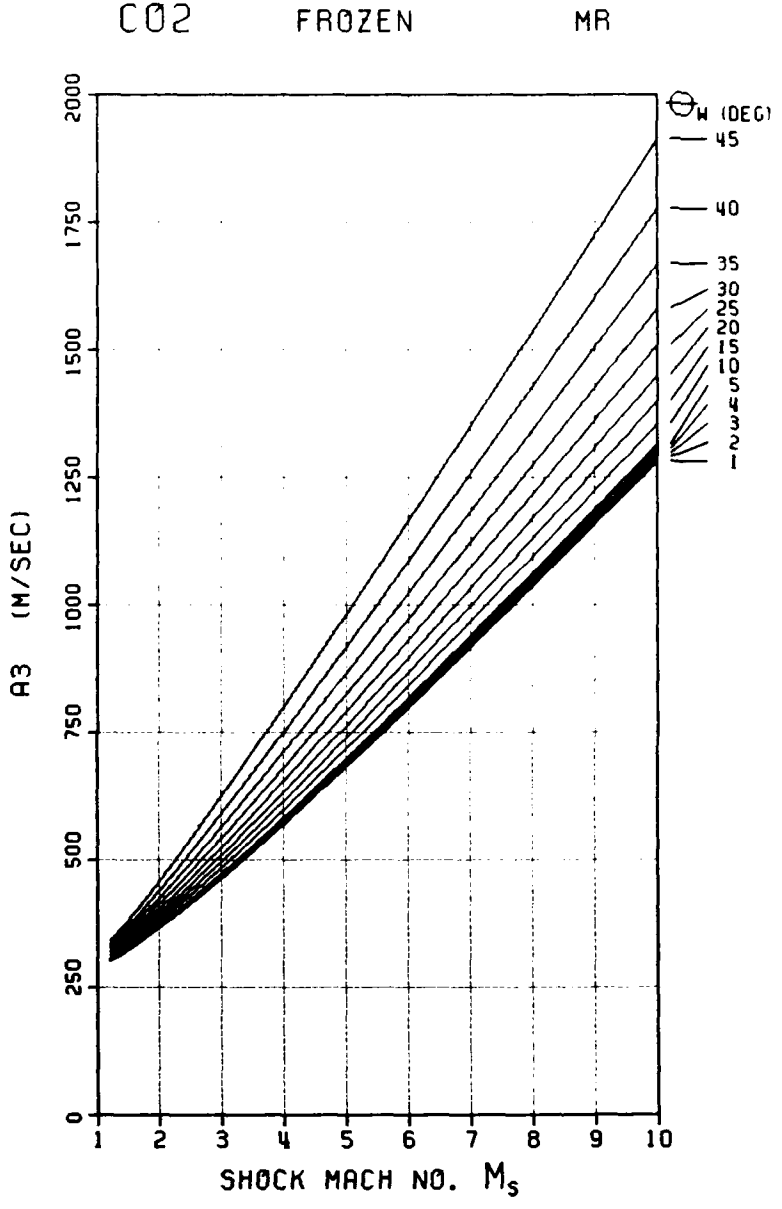
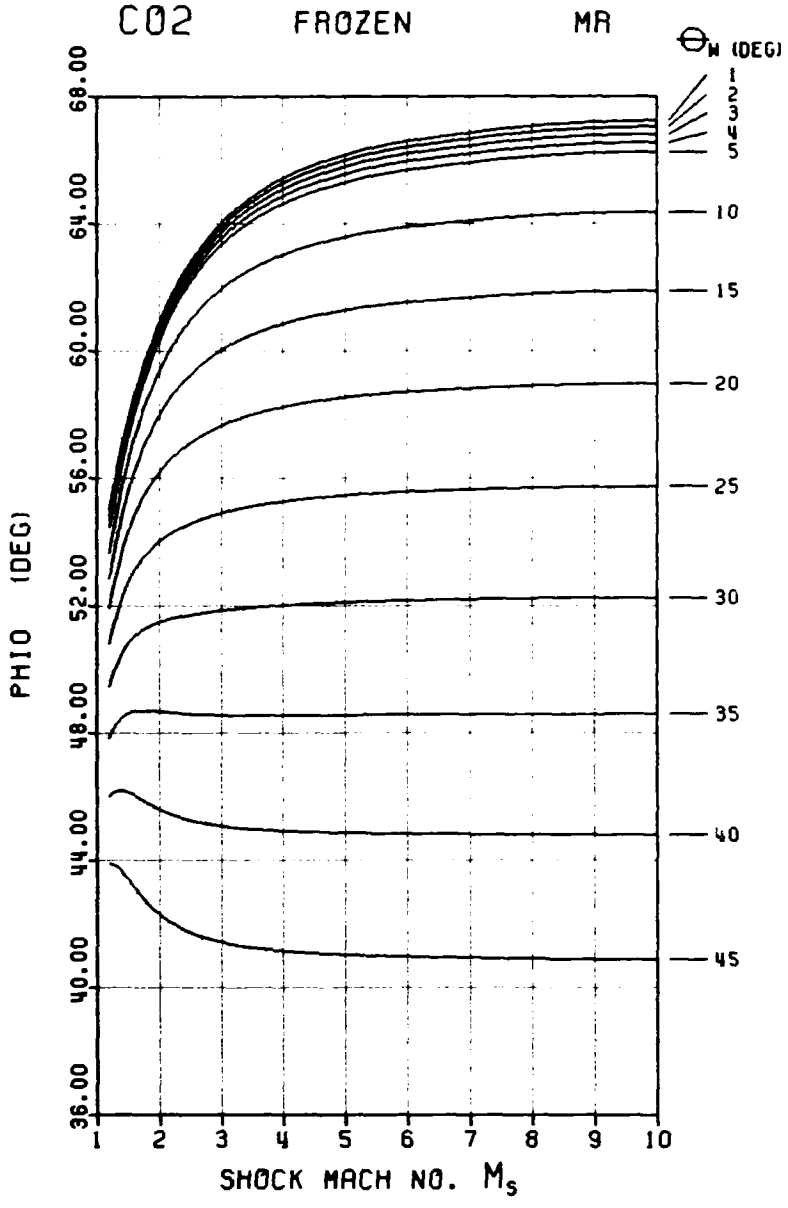
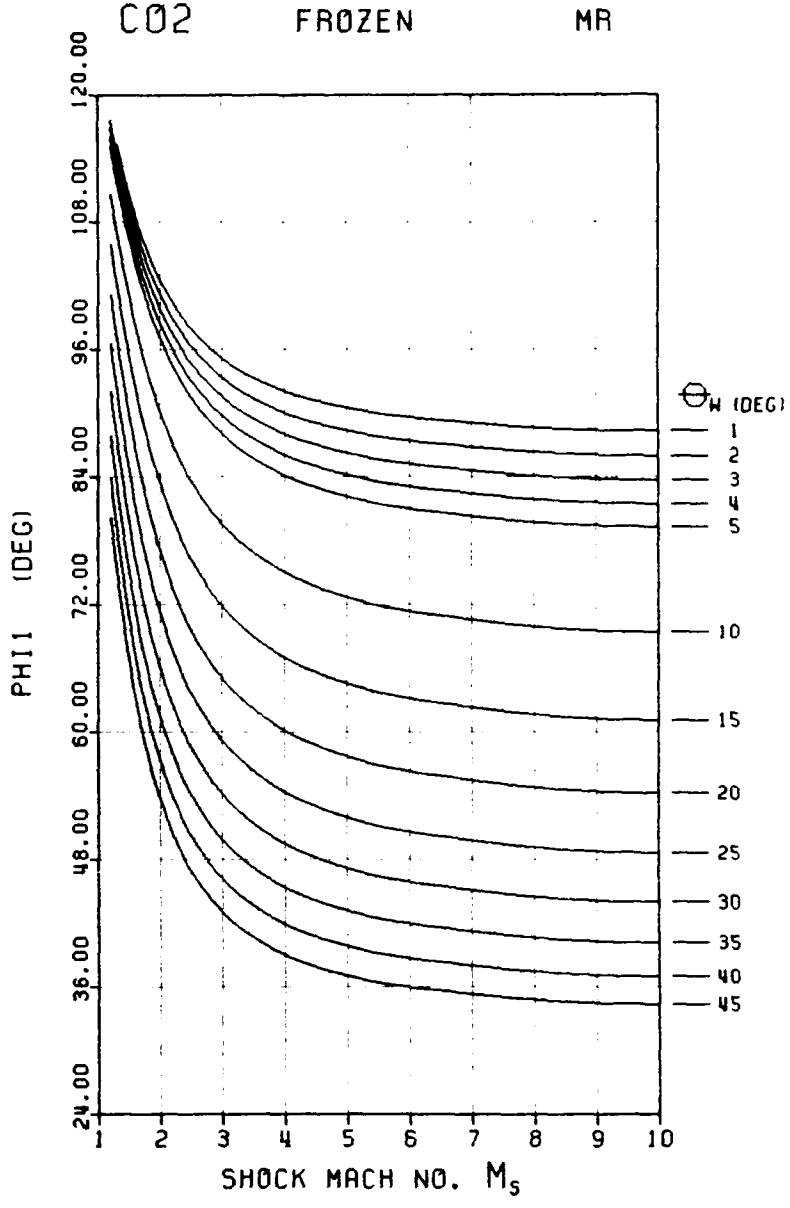
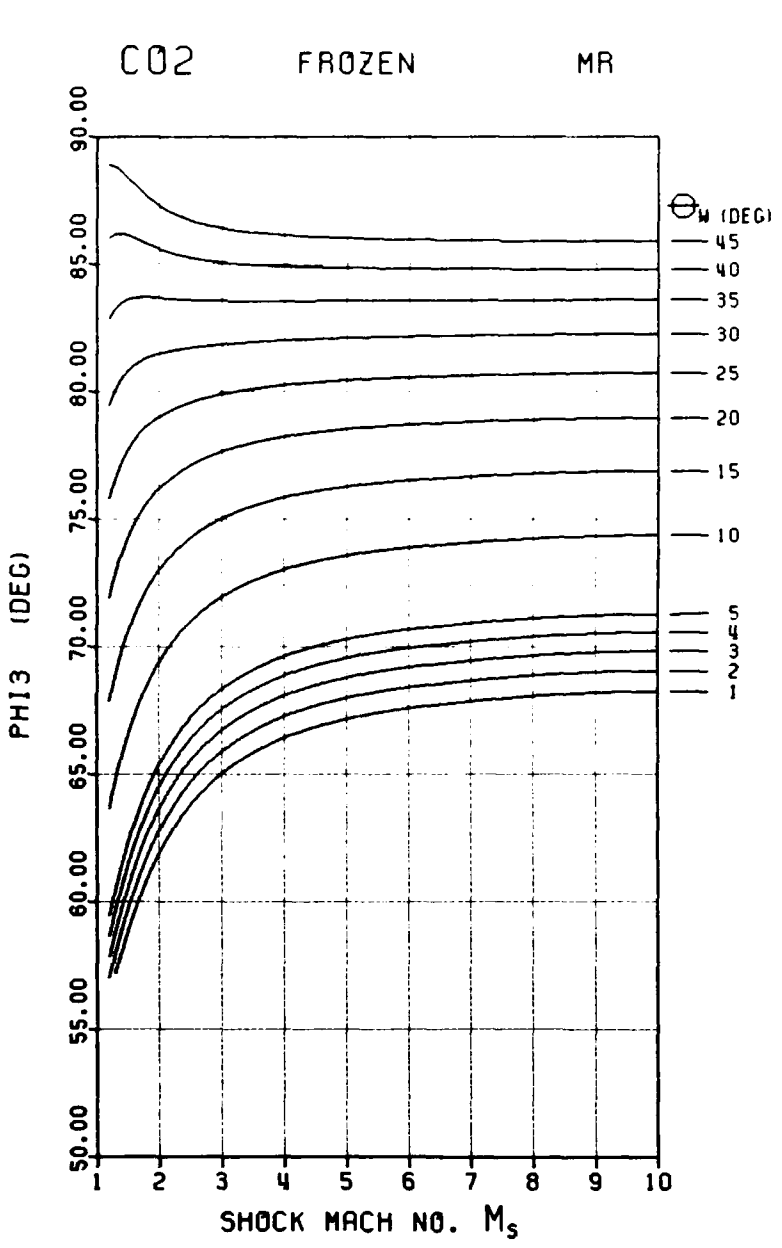
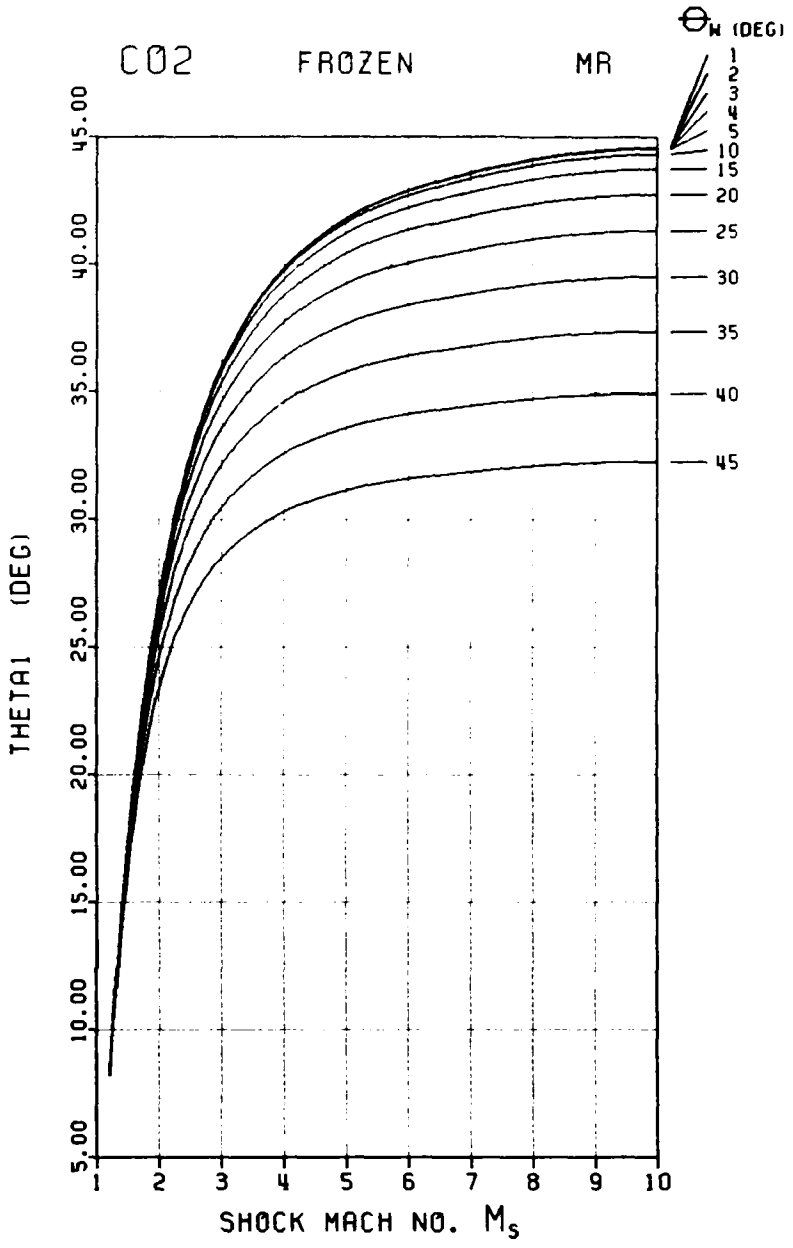
5
4
3
2
1
A2 (M/SEC)
300
450
600
750
900
1050
1200
1350
1500
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

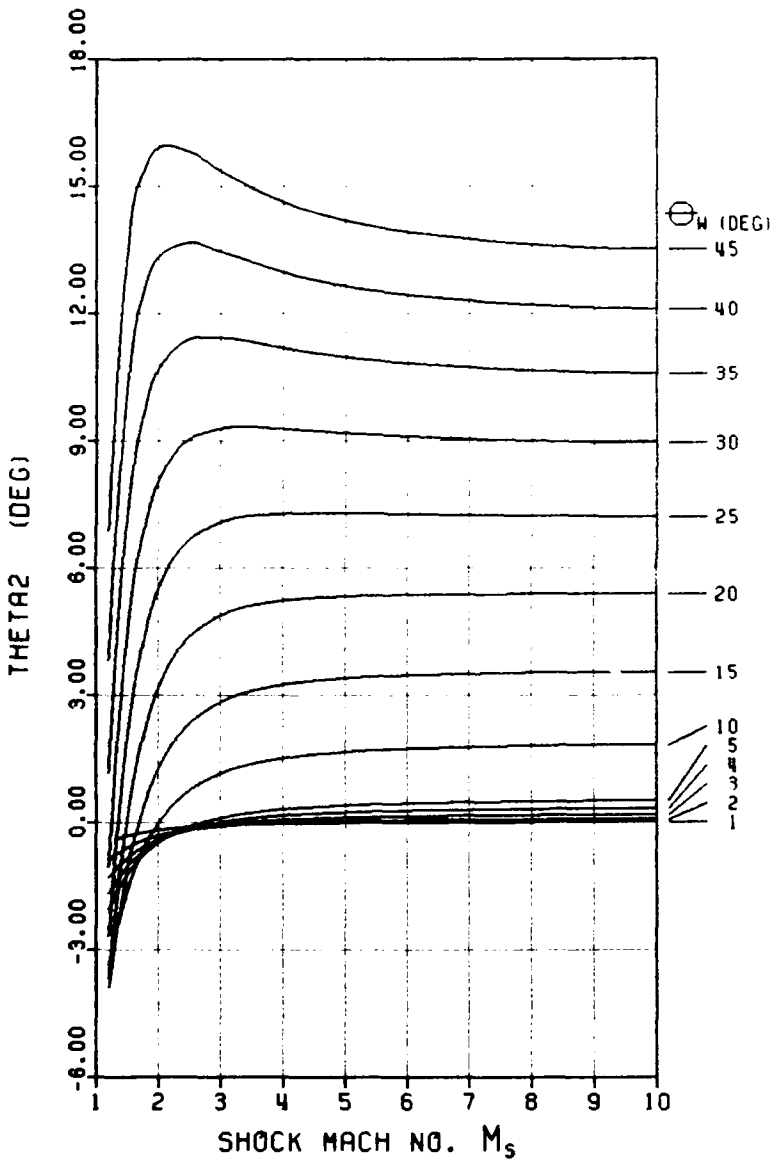

CO2 FROZEN MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A3 (M/SEC)
0
250
500
750
1000
1250
1500
1750
2000
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

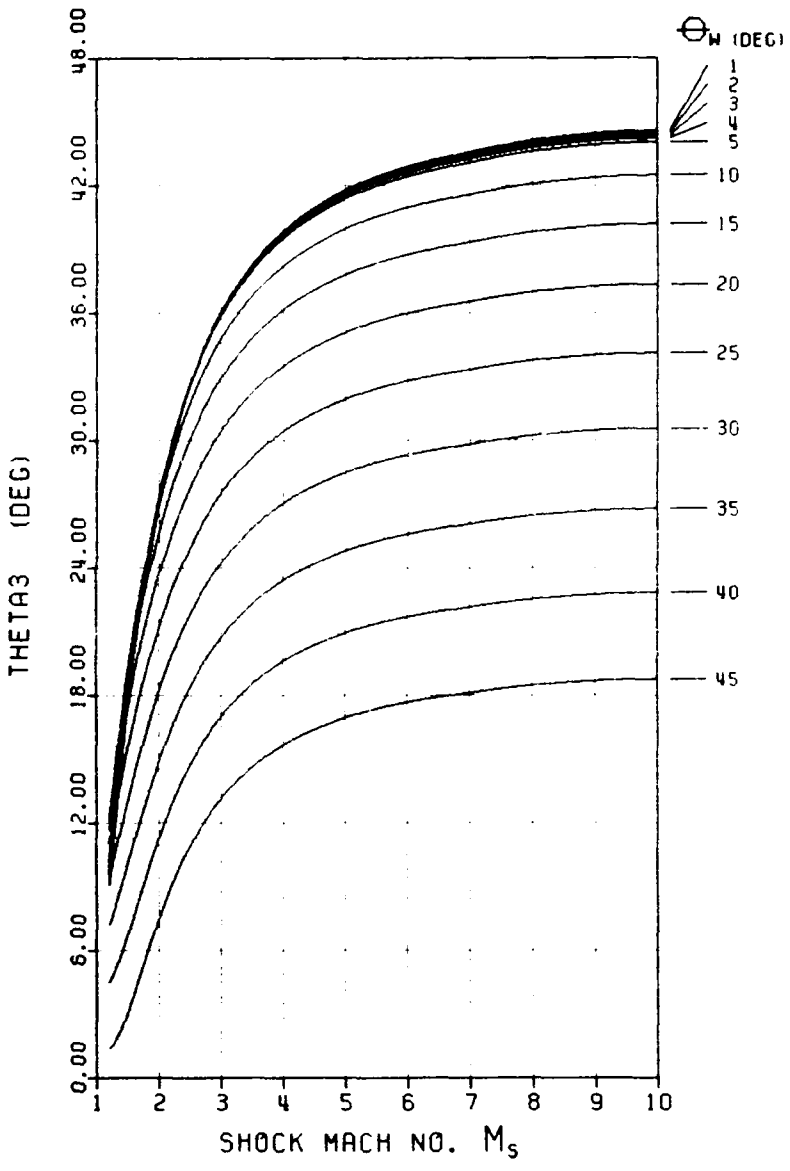

C02 FROZEN MR
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45
PHI0 (DEG)
68.00
64.00
60.00
56.00
52.00
48.00
44.00
40.00
36.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

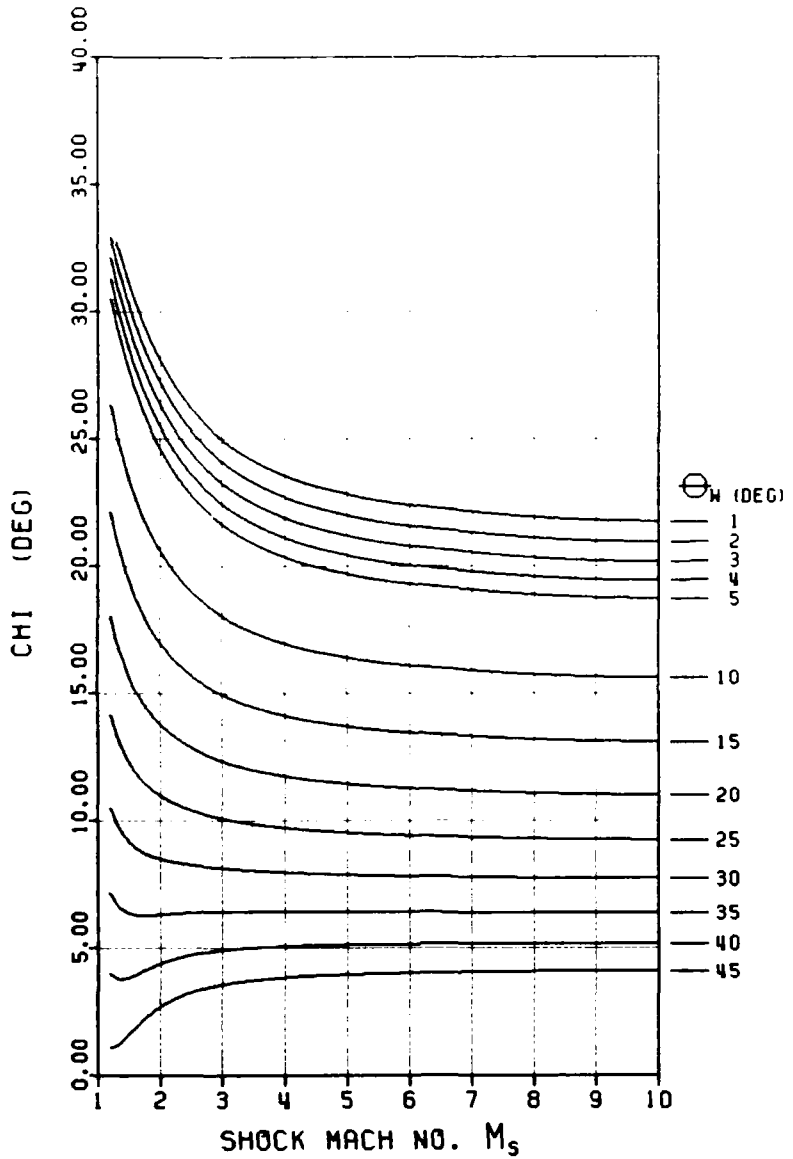

C02 FROZEN MR
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45
PHI1 (DEG)
120.00
108.00
96.00
84.00
72.00
60.00
48.00
36.00
24.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

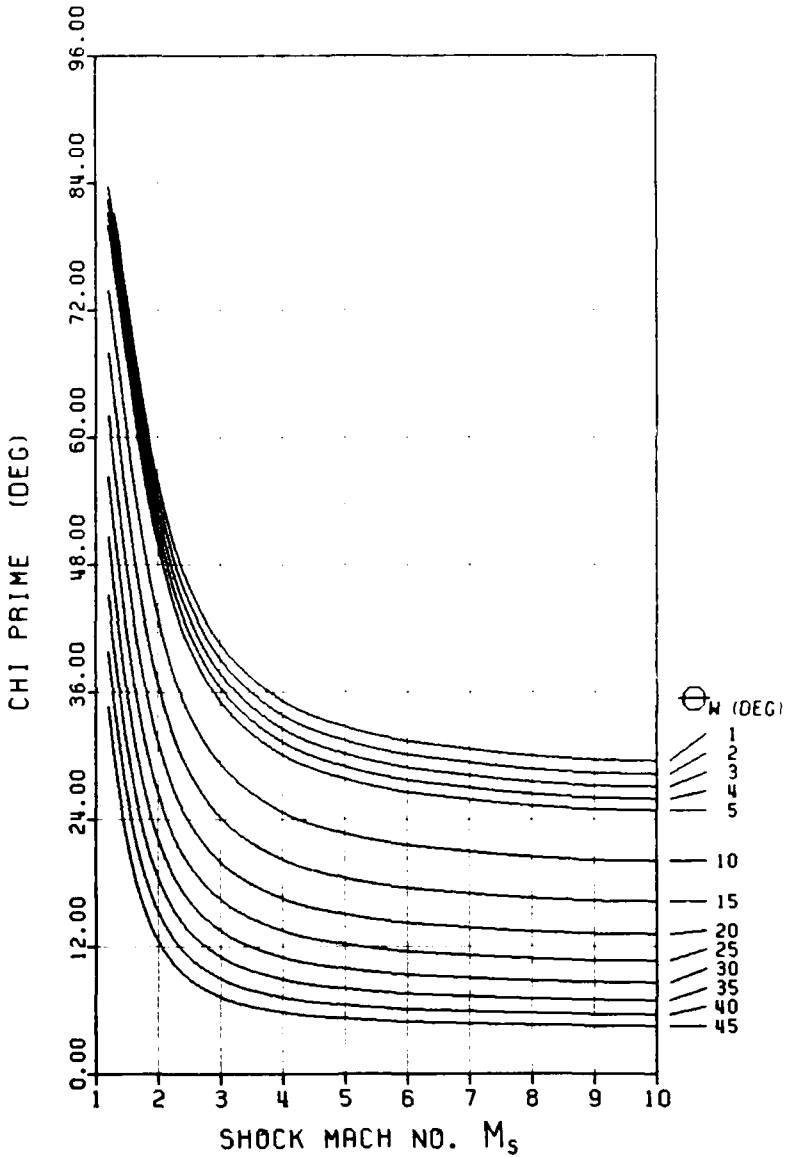

C02 FROZEN MR
PHI3 (DEG)
SHOCK MACH NO. M_S
θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

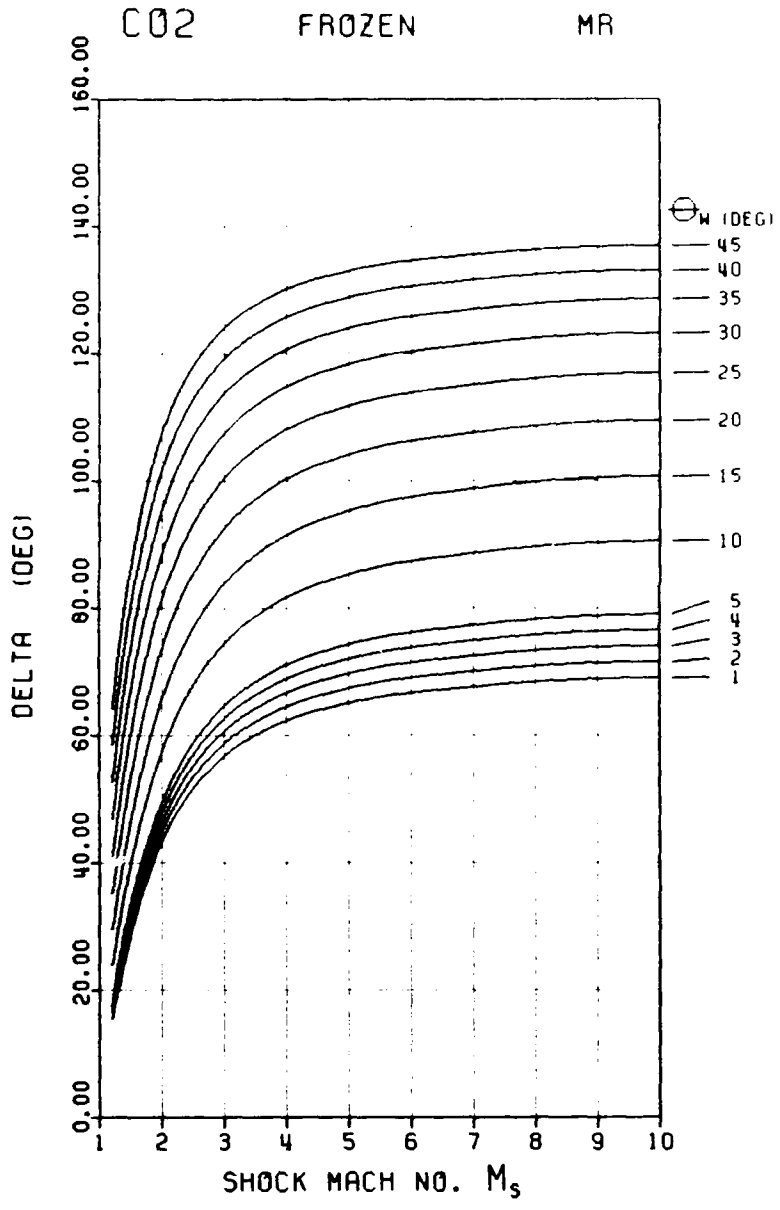

C02 FROZEN MR
THETA1 (DEG)
SHOCK MACH NO. M_S
θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

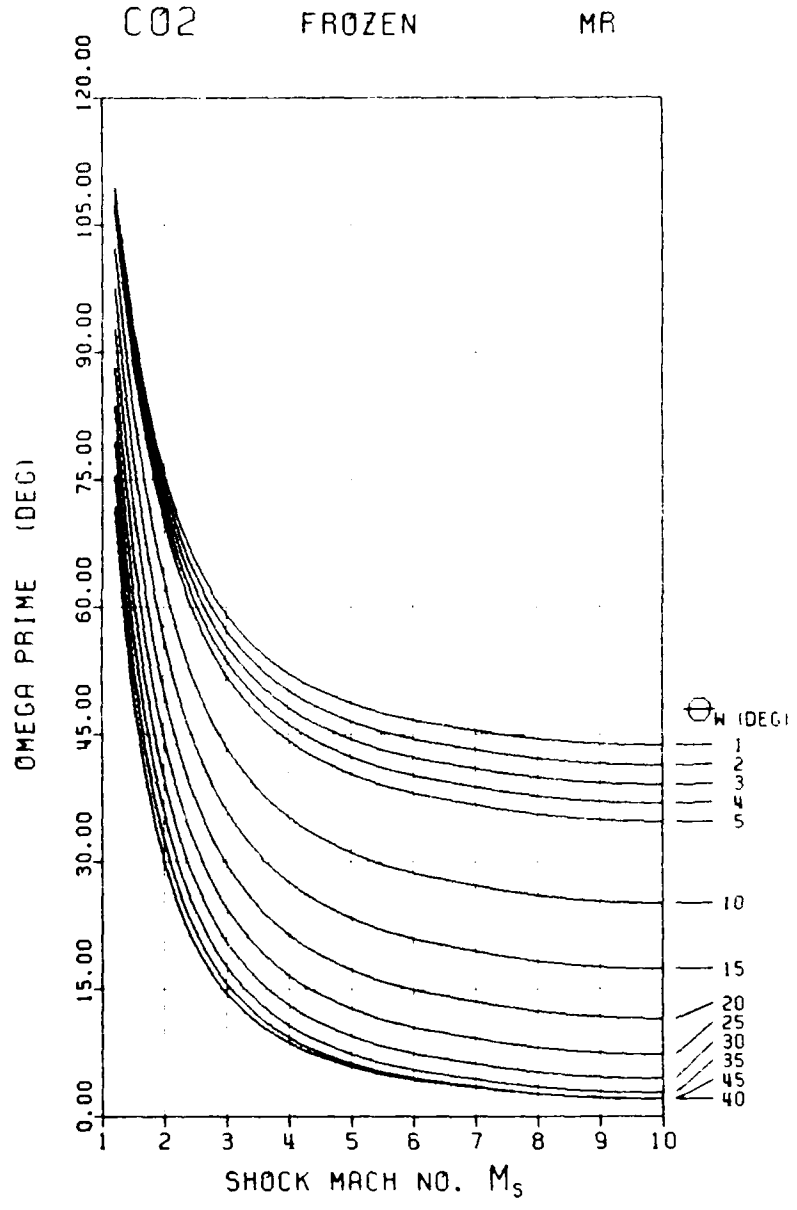

C02 FROZEN MR
THETA2 (DEG)
18.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

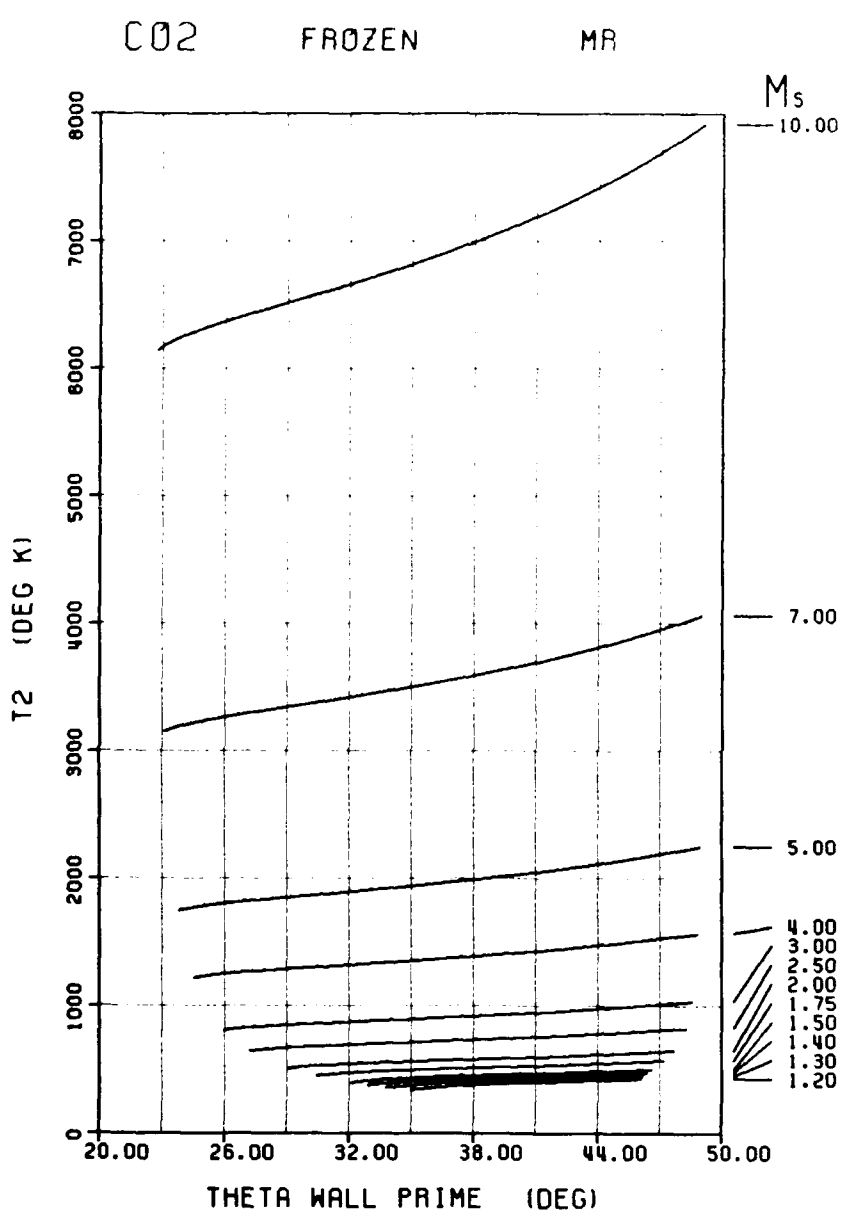

C02 FROZEN MR
THETA3 (DEG)
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

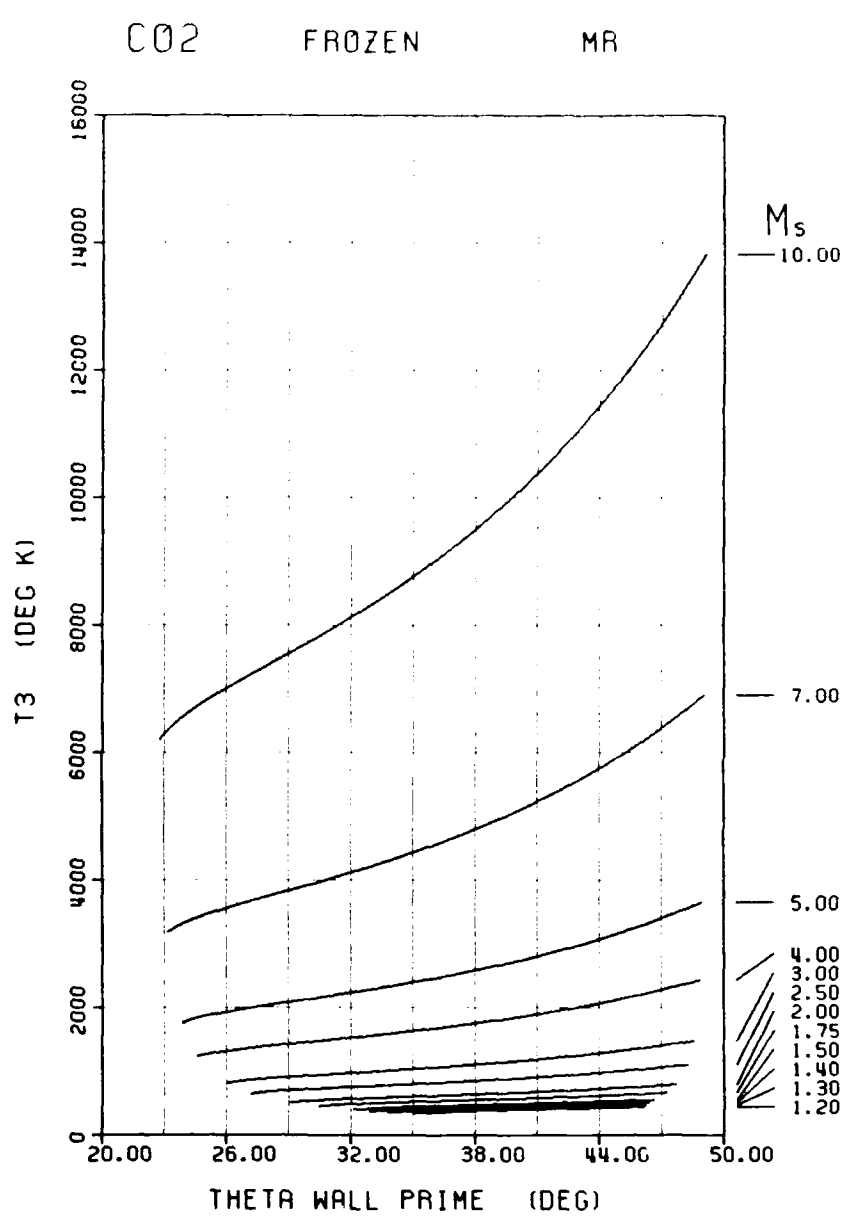

C02 FROZEN MR
CHI (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

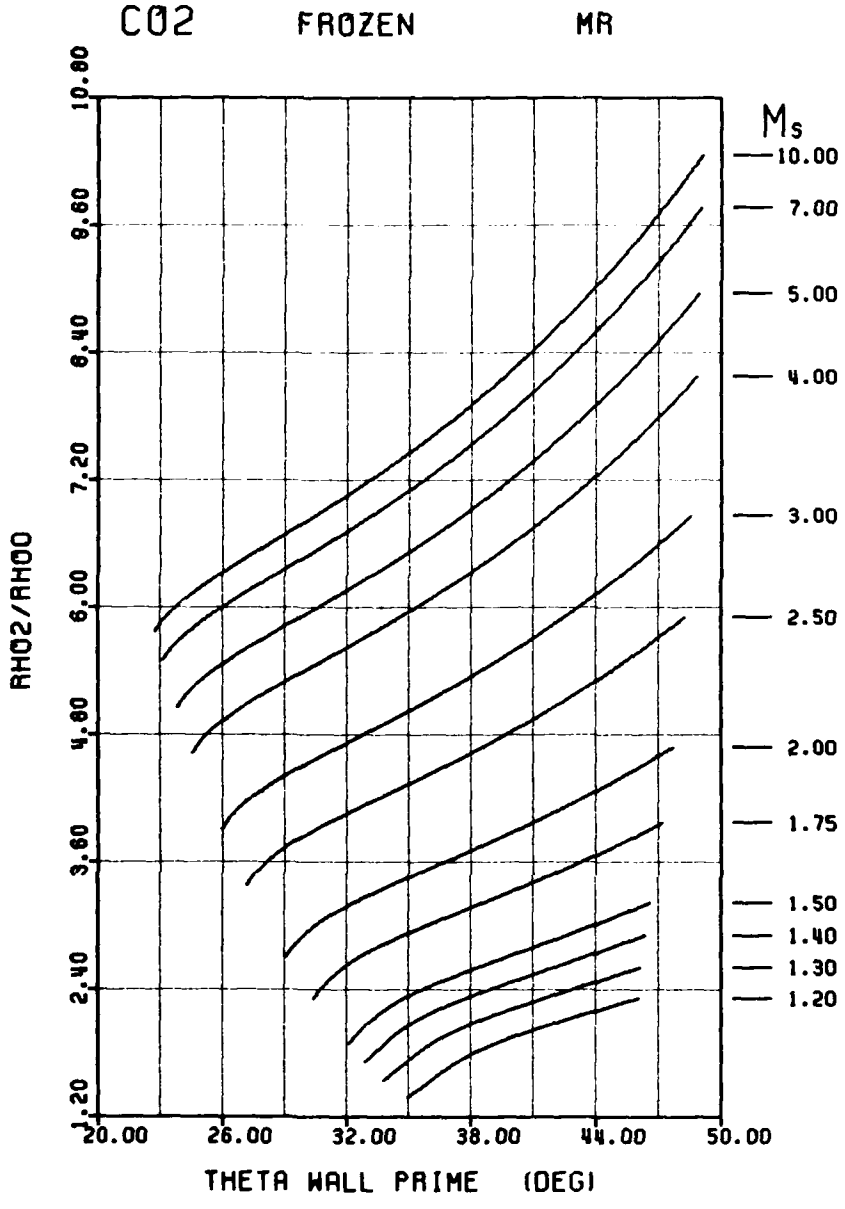

C02 FROZEN MR
CHI PRIME (DEG)
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

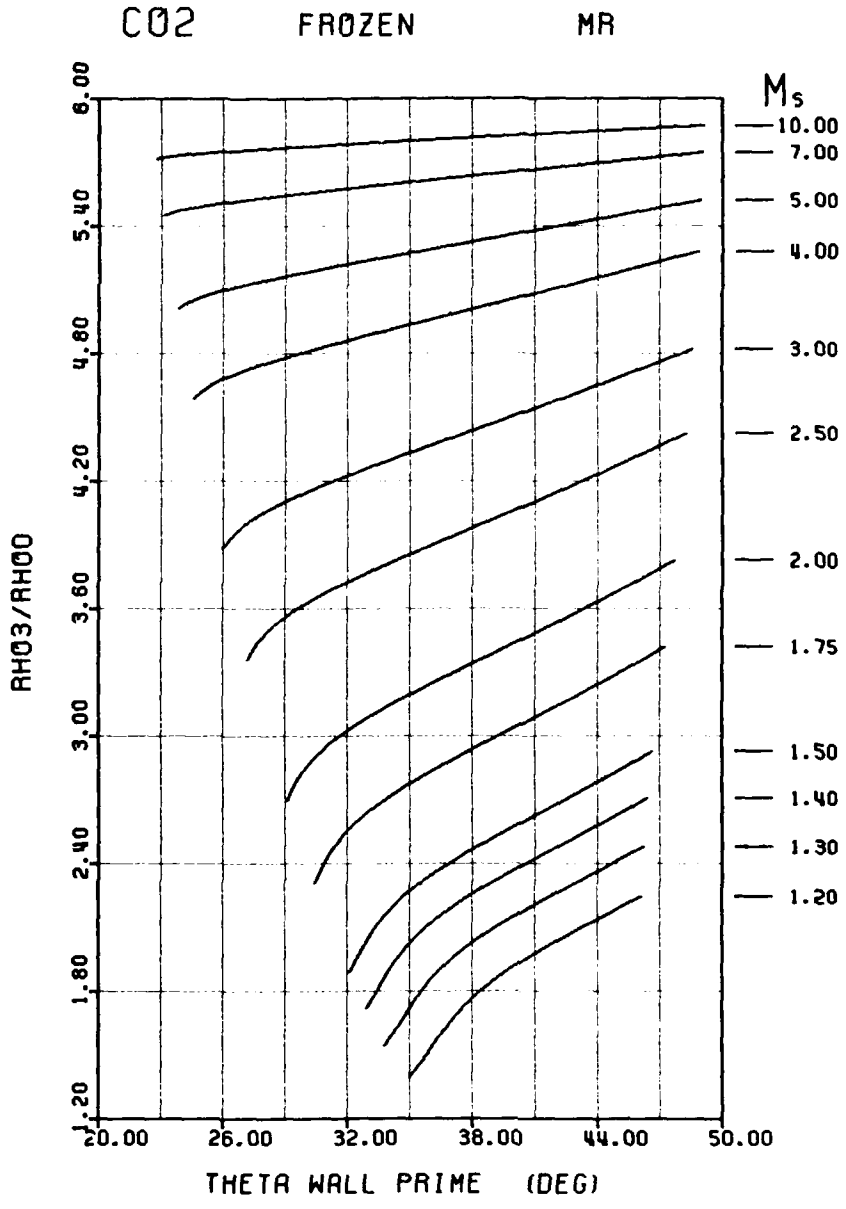

CO2 FROZEN MR
DELTA (DEG)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
θ_w (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

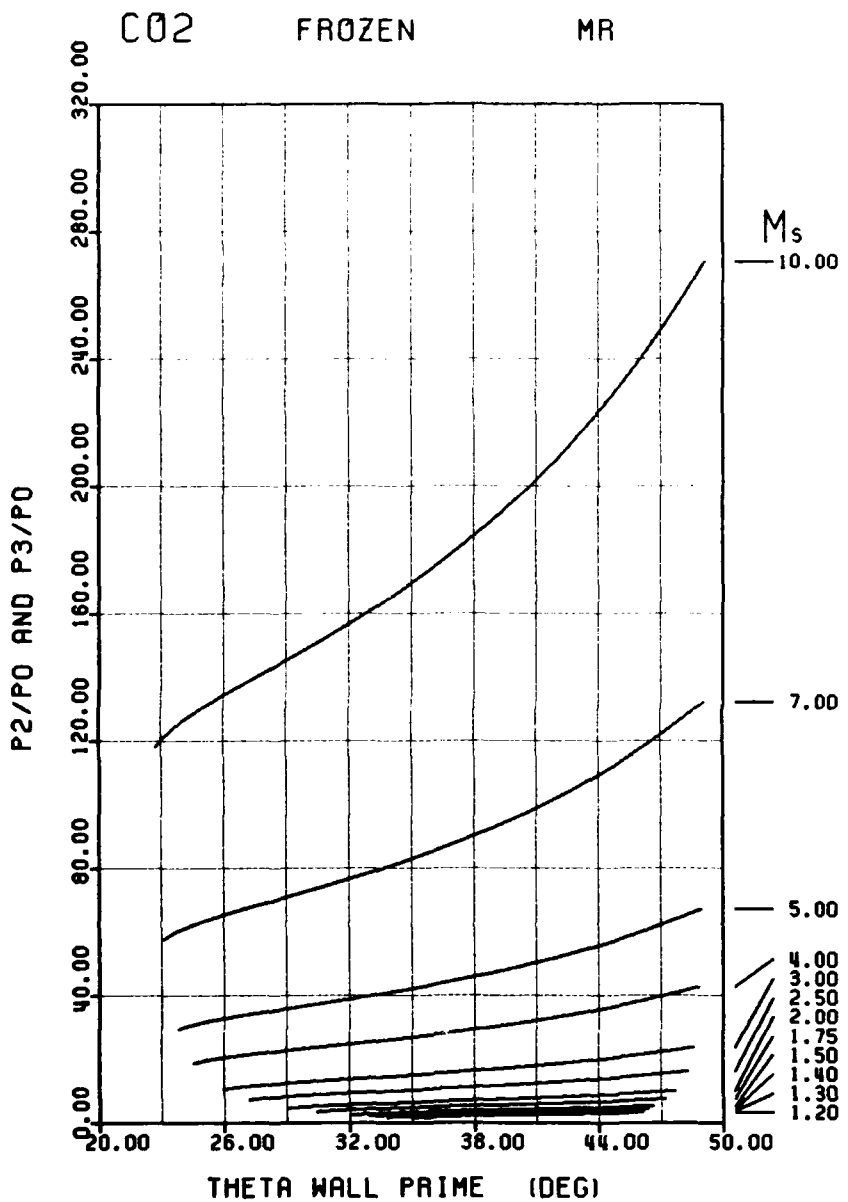

CO2 FROZEN MR
OMEGA PRIME (DEG)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
θ_w (DEG)
1
2
3
4
5
10
15
20
25
30
35
45
40

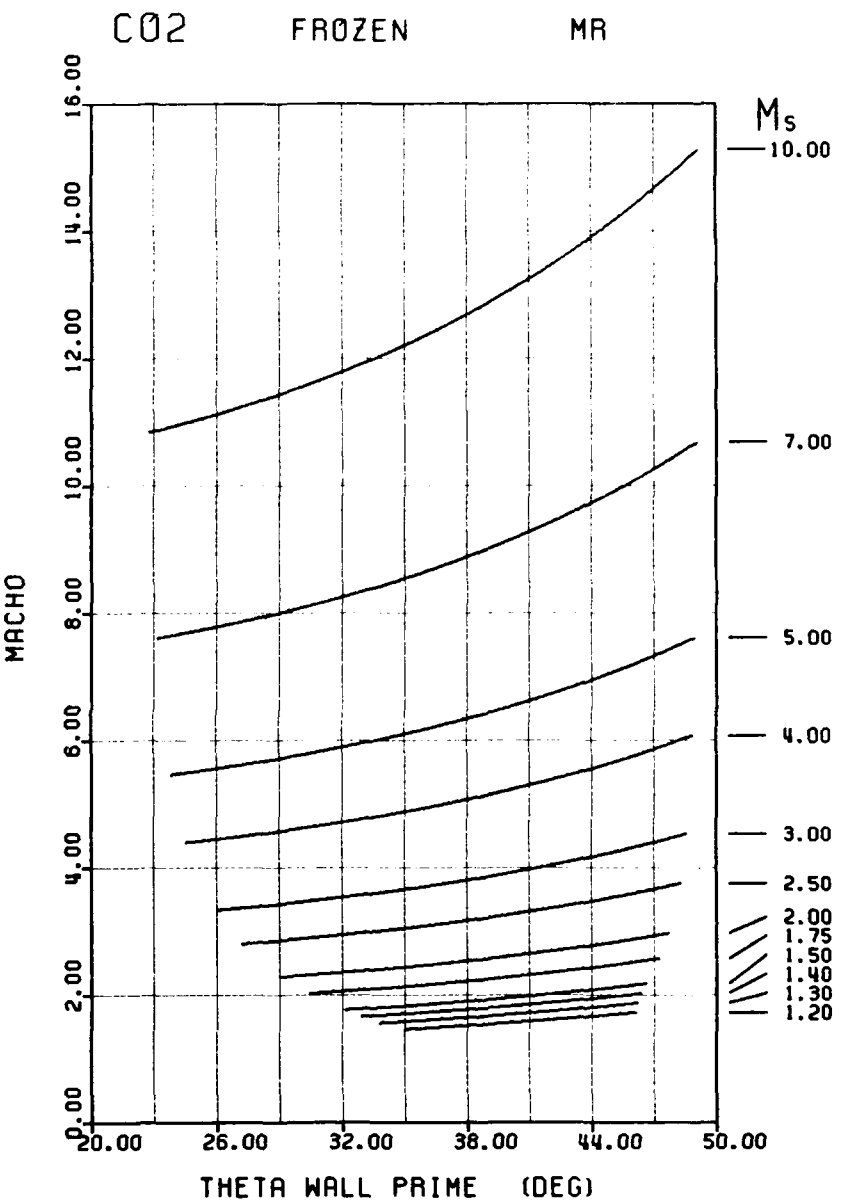

C02 FROZEN MR
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
T2 (DEG K)
0
1000
2000
3000
4000
5000
6000
7000
8000
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)

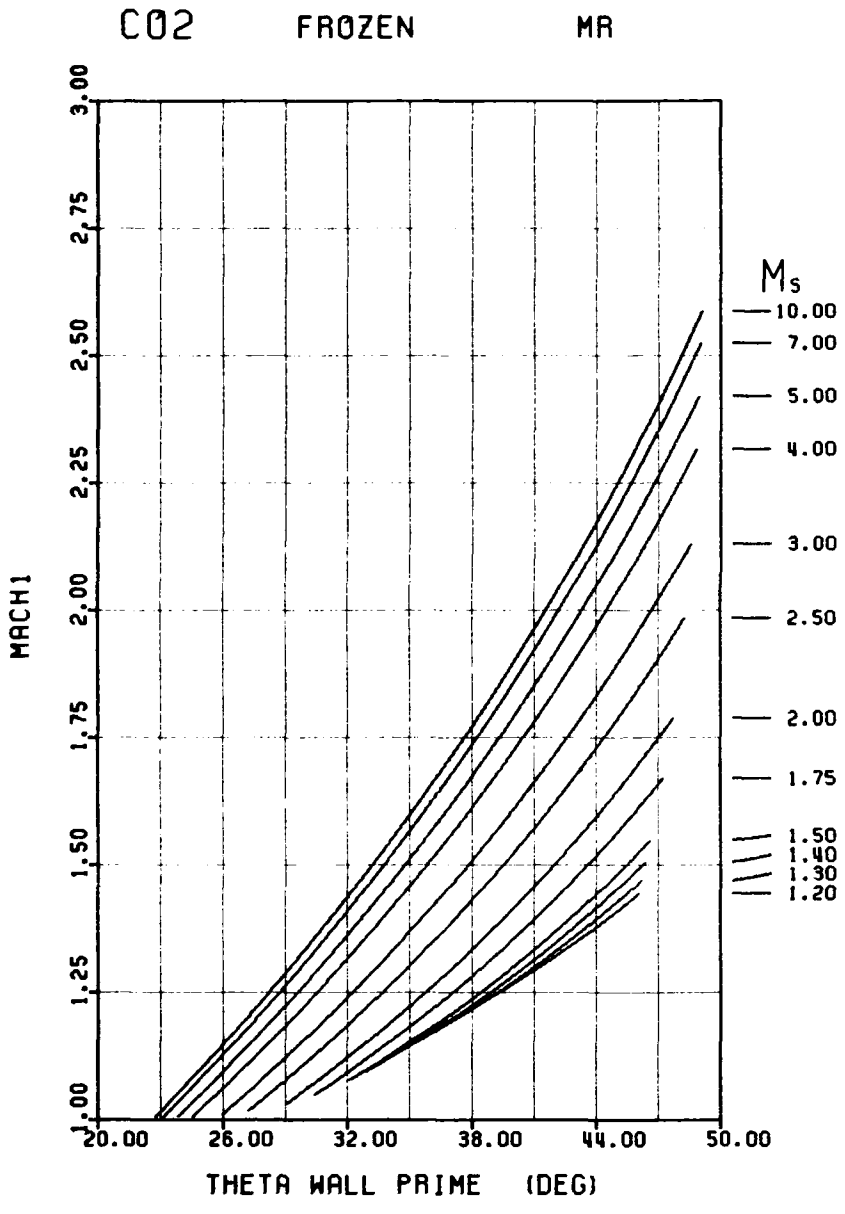

C02 FROZEN MR
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
T3 (DEG K)
0
2000
4000
6000
8000
10000
12000
14000
16000
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)

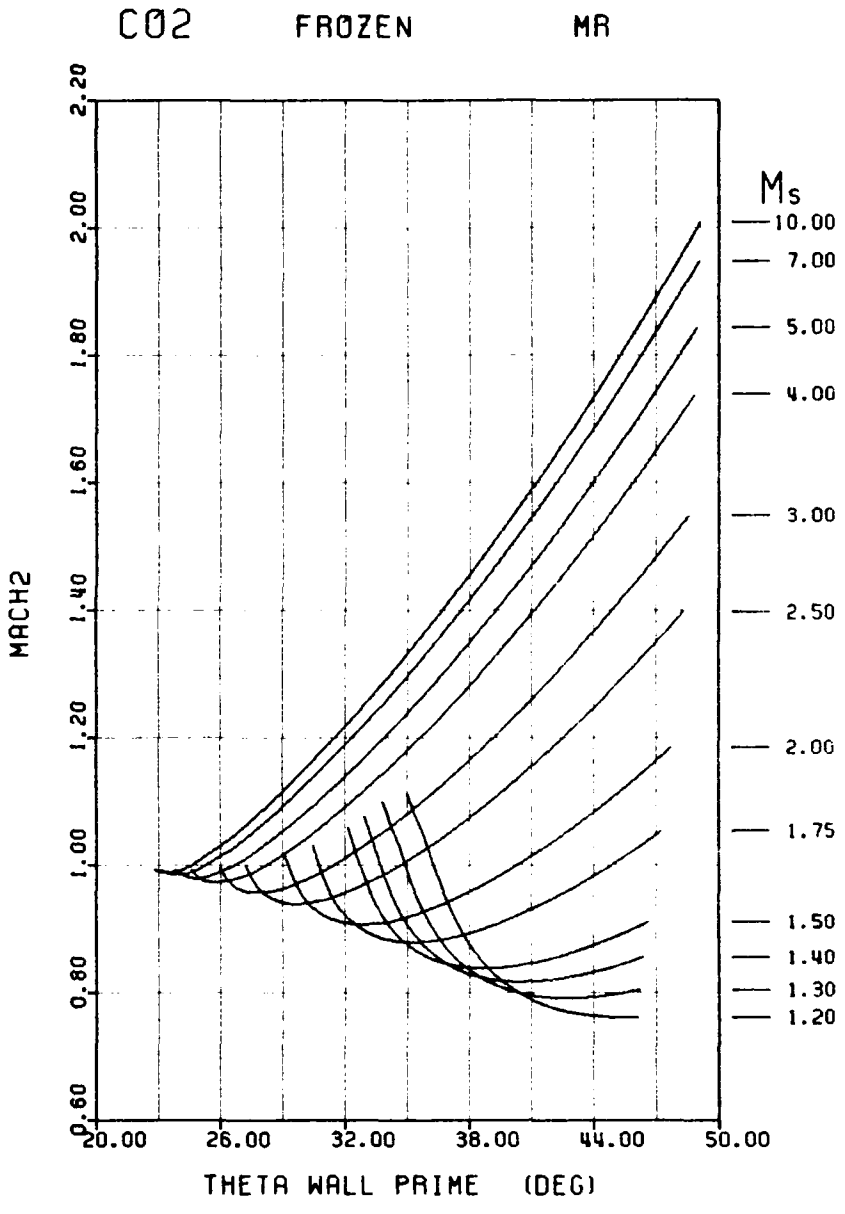

C02 FROZEN MR
RH02/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
10.80
9.60
8.40
7.20
6.00
4.80
3.60
2.40
1.20
20.00
26.00
32.00
38.00
44.00
50.00

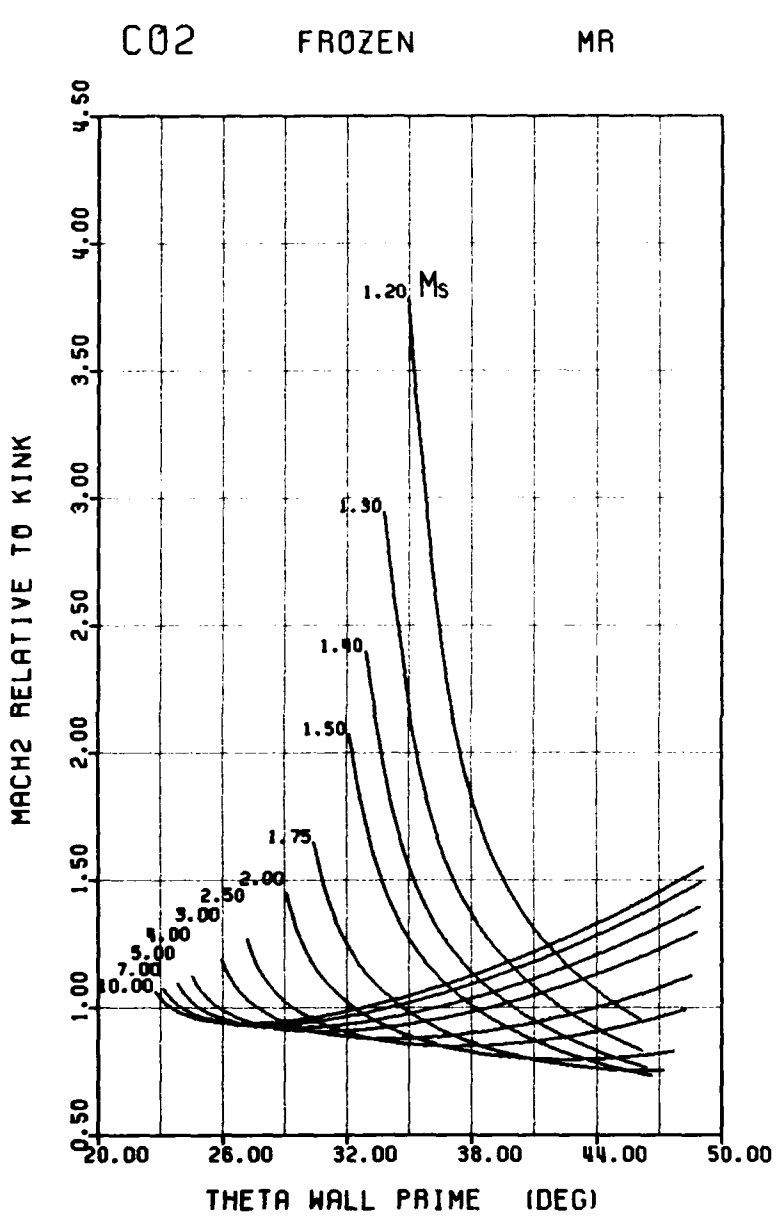

C02 FROZEN MR
RH03/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
6.00
5.40
4.80
4.20
3.60
3.00
2.40
1.80
1.20
20.00
26.00
32.00
38.00
44.00
50.00

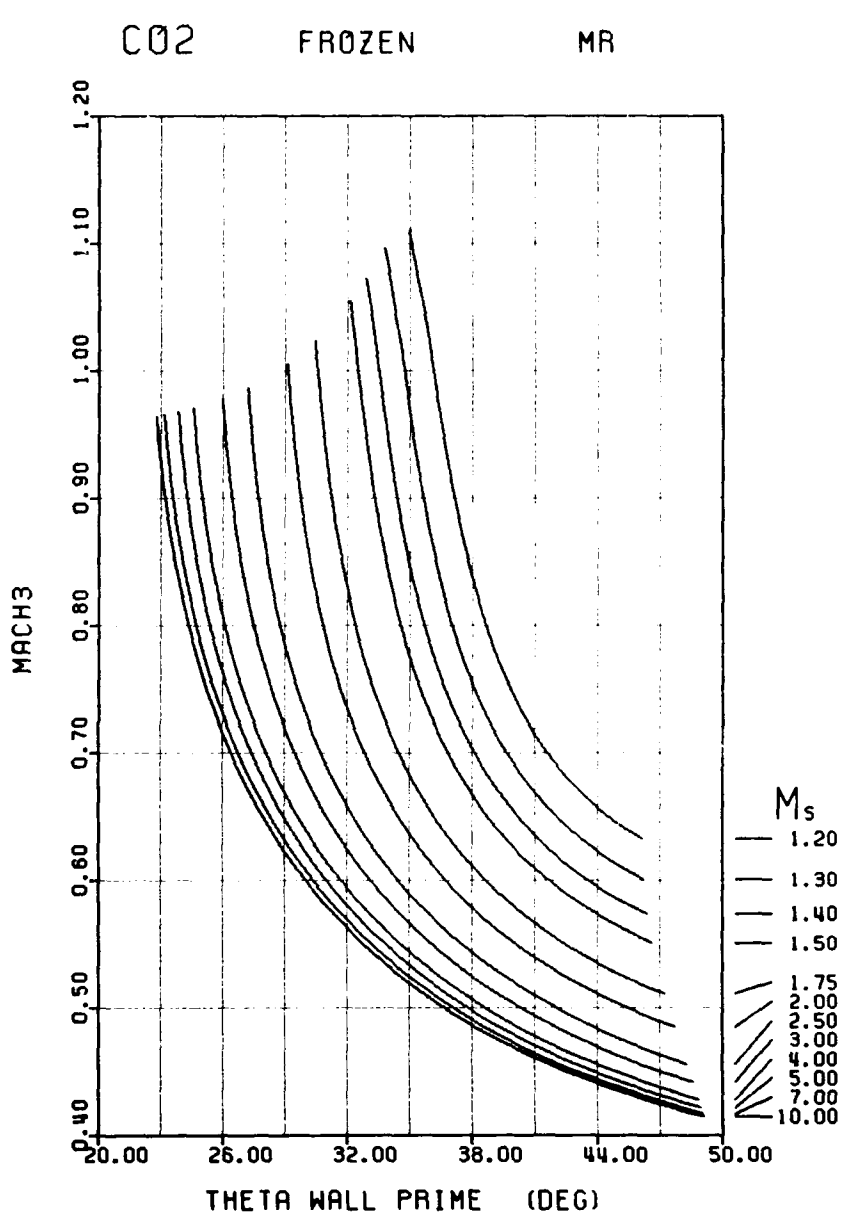

C02 FROZEN MR
P2/P0 AND P3/P0
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

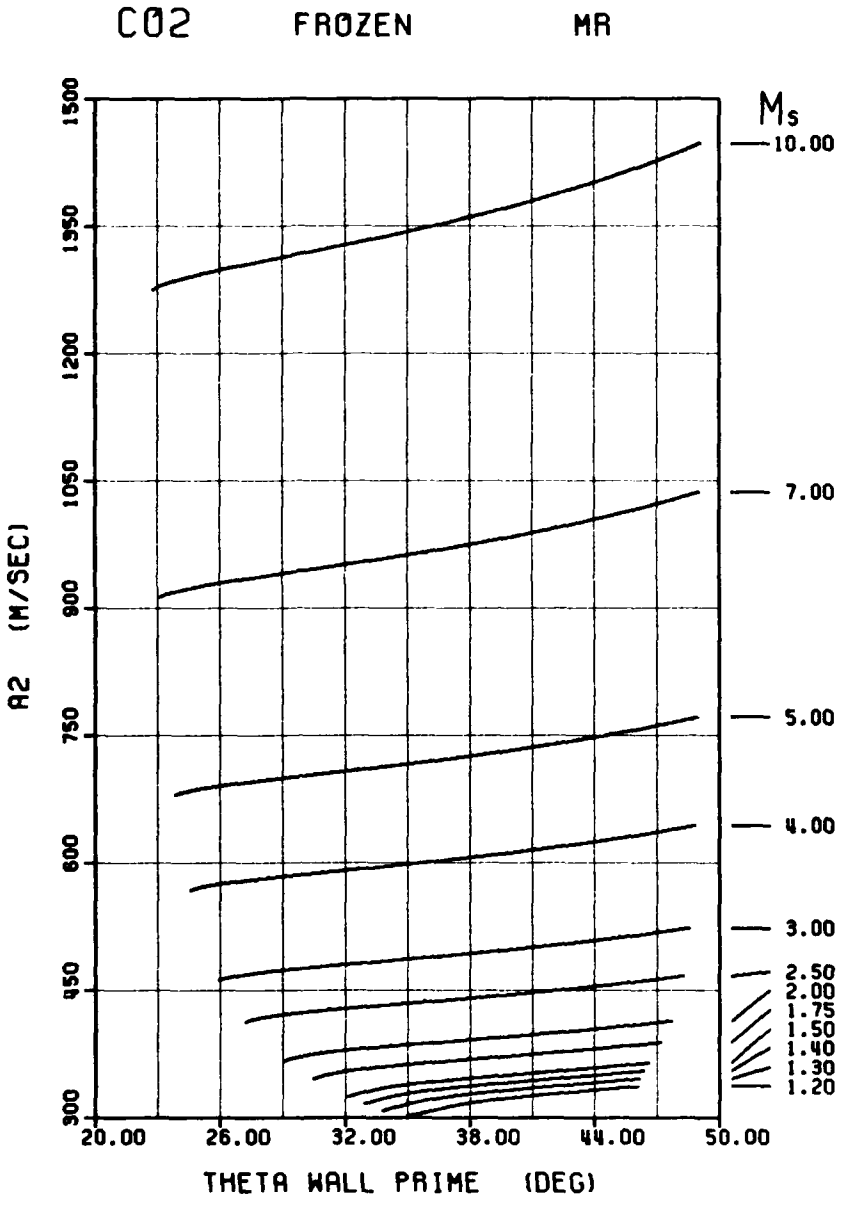

C02 FROZEN MR
MACHO
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

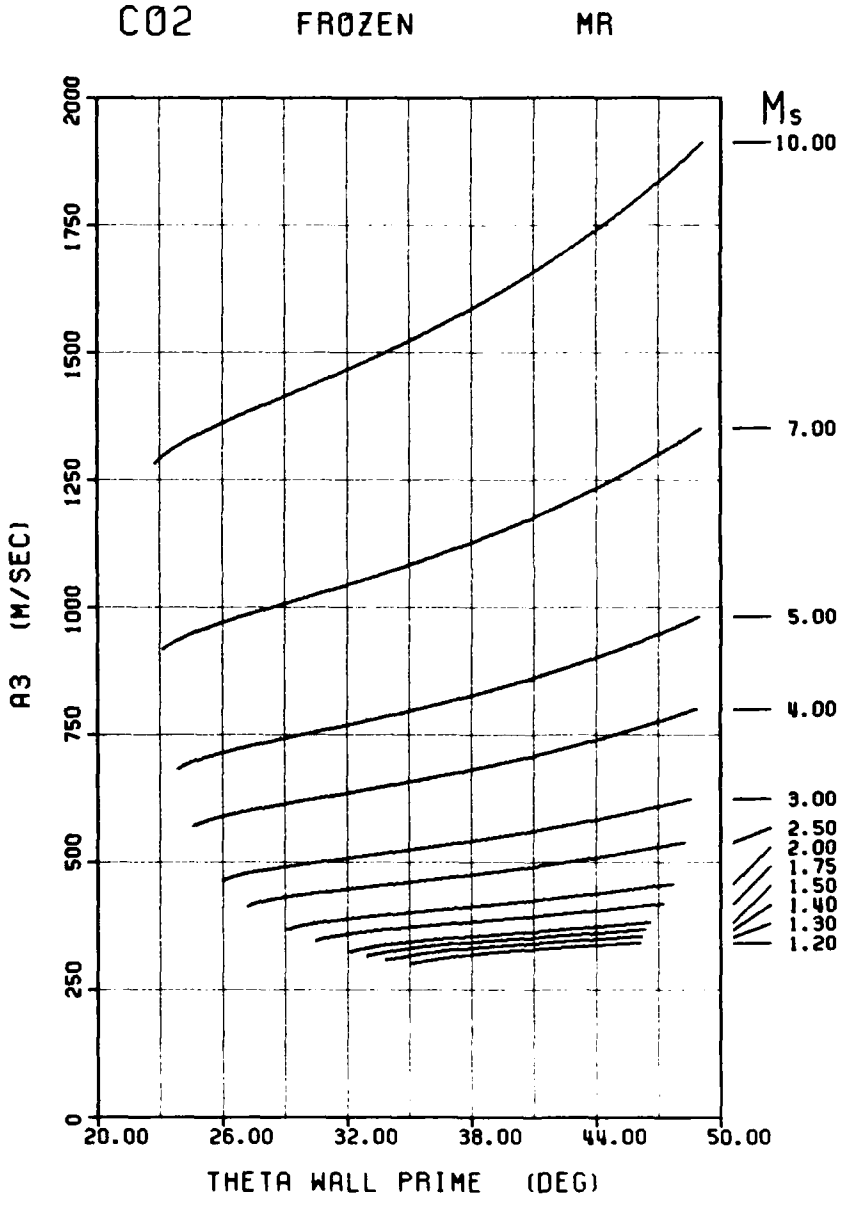

C02 FROZEN MR
MACH1
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

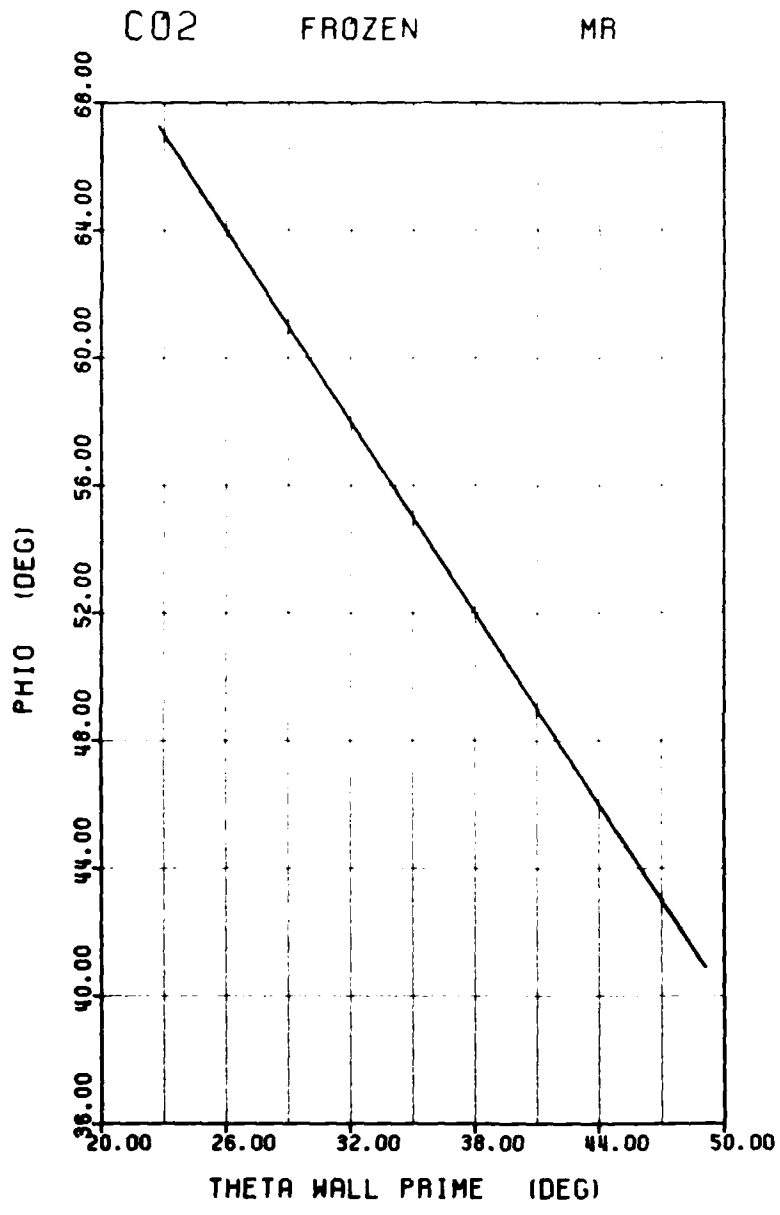

C02 FROZEN MR
MACH2
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

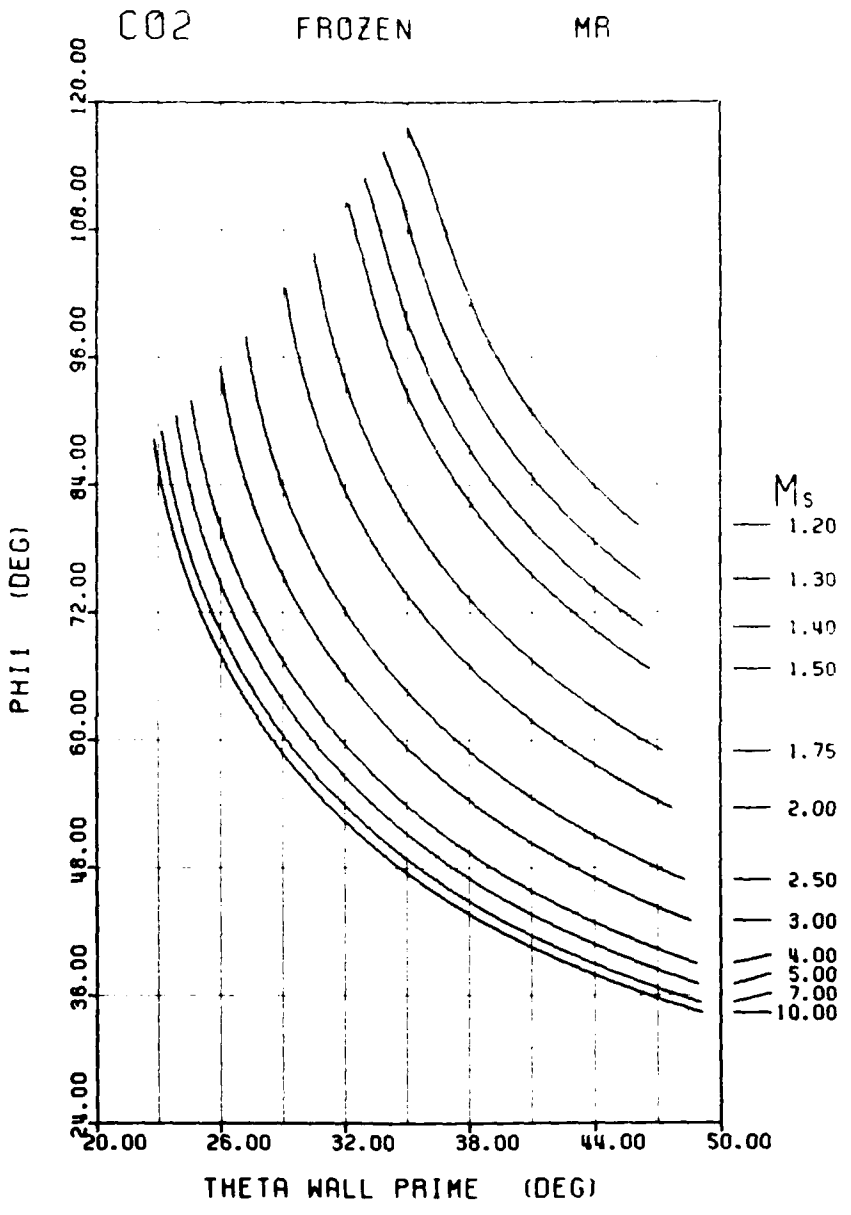

C02 FROZEN MR
MACH2 RELATIVE TO KINK
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
5.00
7.00
10.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
20.00
26.00
32.00
38.00
44.00
50.00

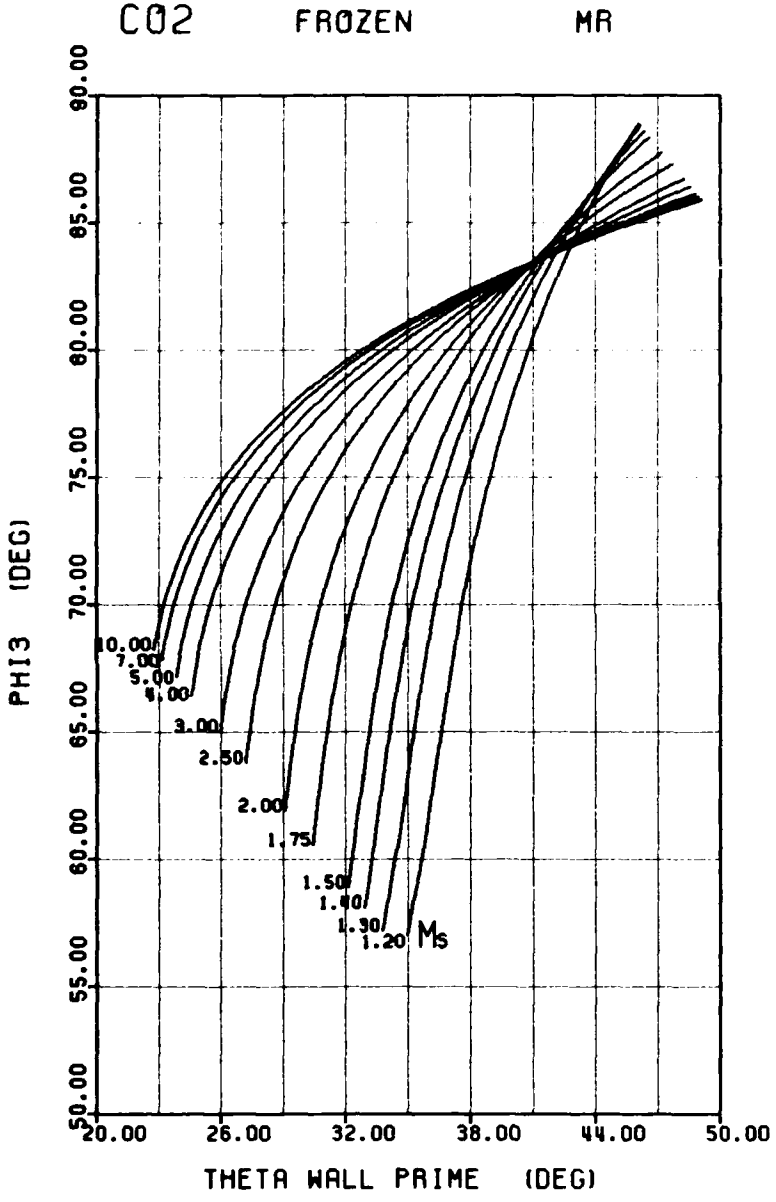

C02 FROZEN MR
MACH3
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
20.00
26.00
32.00
38.00
44.00
50.00

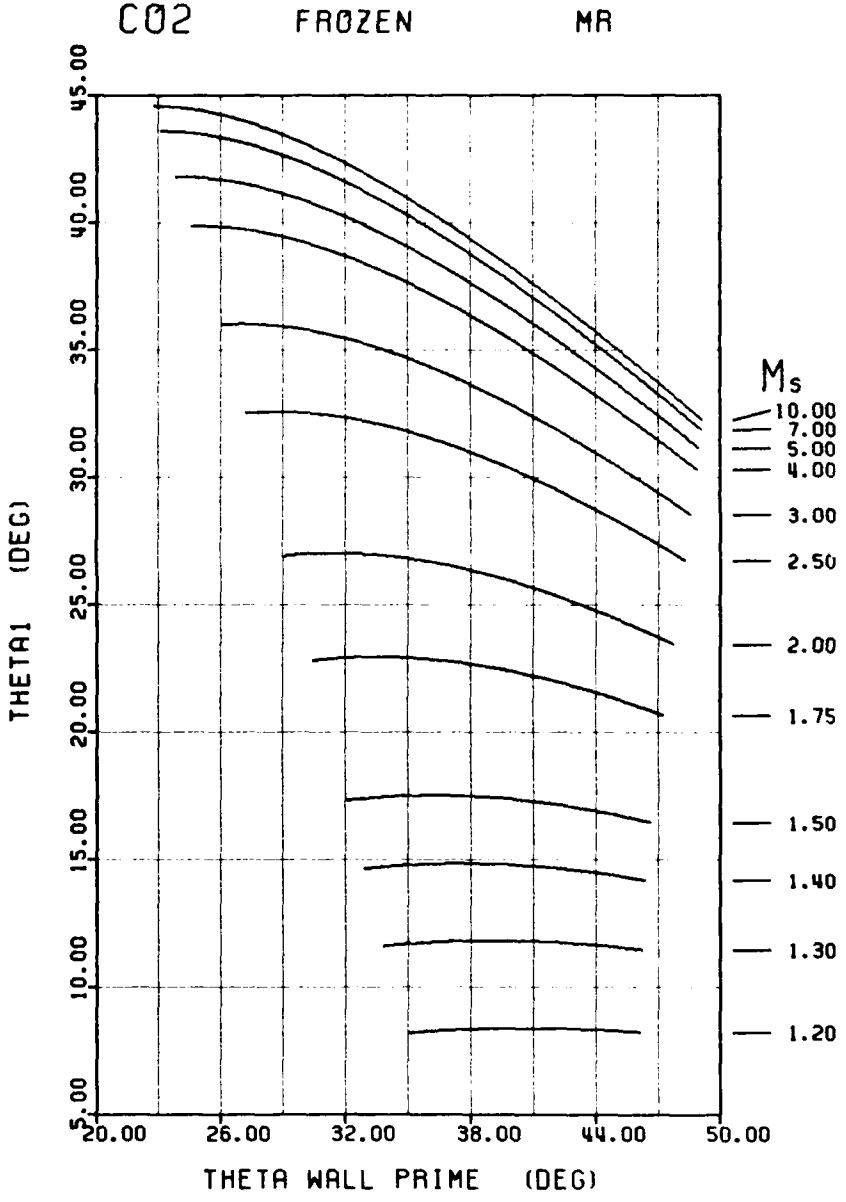

C02 FROZEN MR
A2 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
300
450
600
750
900
1050
1200
1350
1500
20.00
26.00
32.00
38.00
44.00
50.00

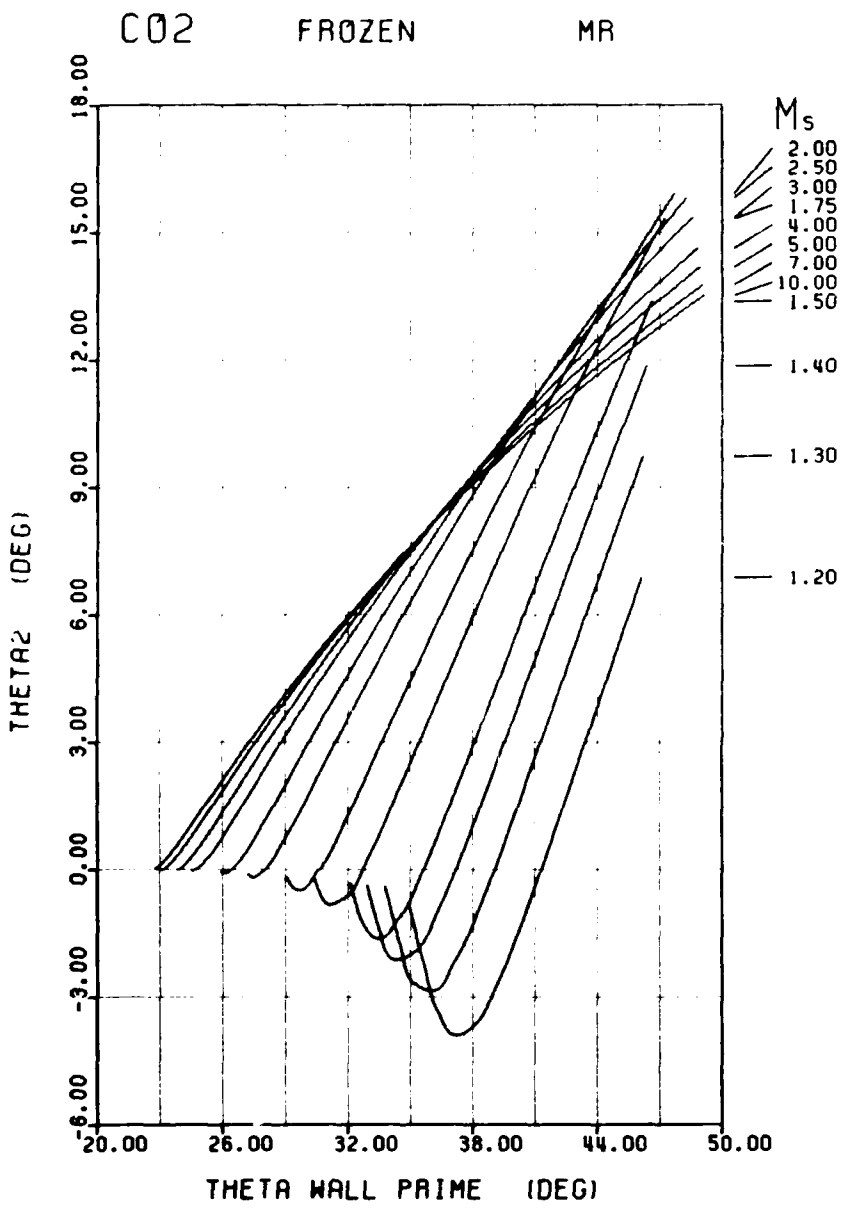

C02 FROZEN MR
A3 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
250
500
750
1000
1250
1500
1750
2000
20.00
26.00
32.00
38.00
44.00
50.00

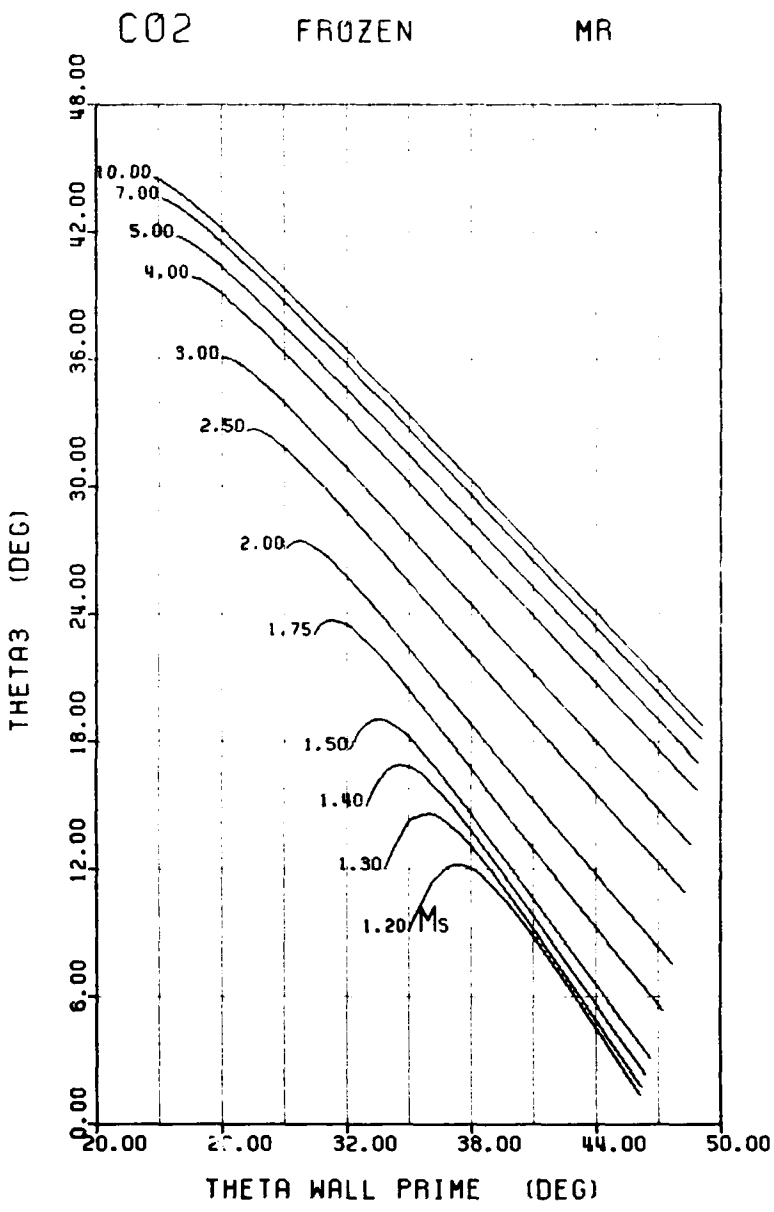

C02 FROZEN MR
PHI0 (DEG)
68.00
64.00
60.00
56.00
52.00
48.00
44.00
40.00
36.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)

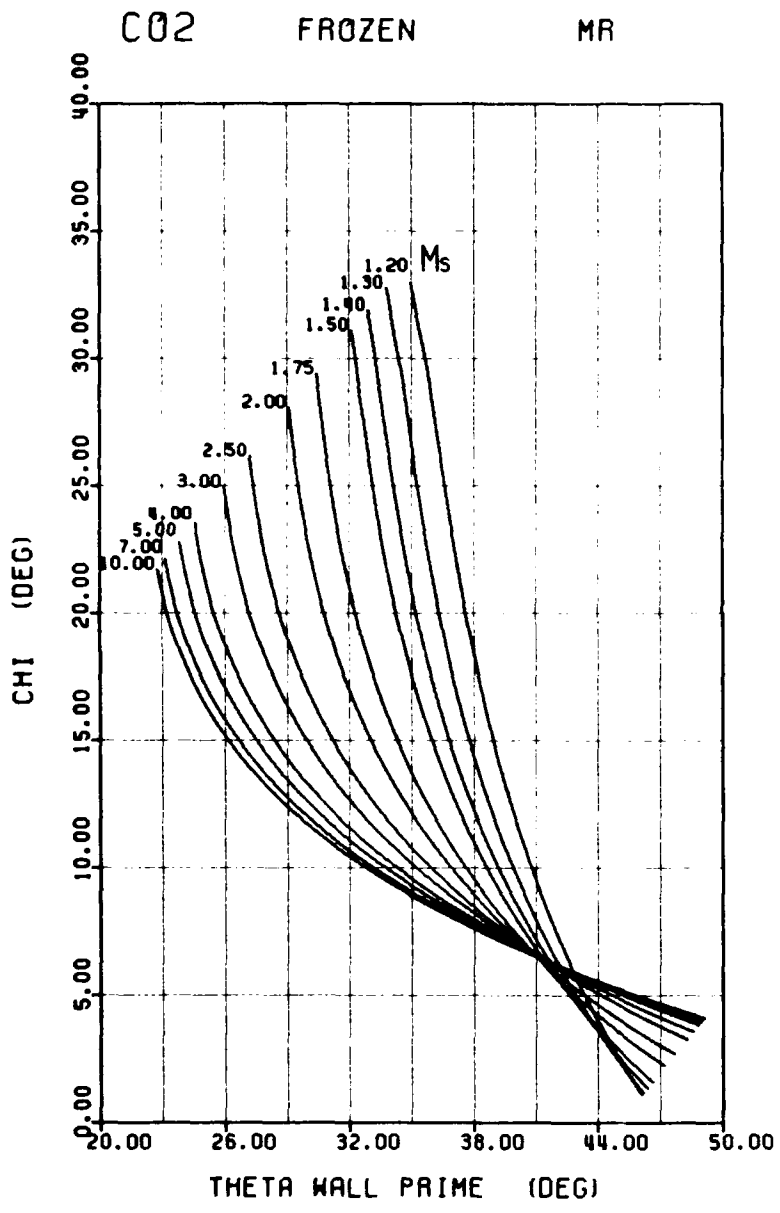

C02 FROZEN MR
PHI1 (DEG)
120.00
108.00
96.00
84.00
72.00
60.00
48.00
36.00
24.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

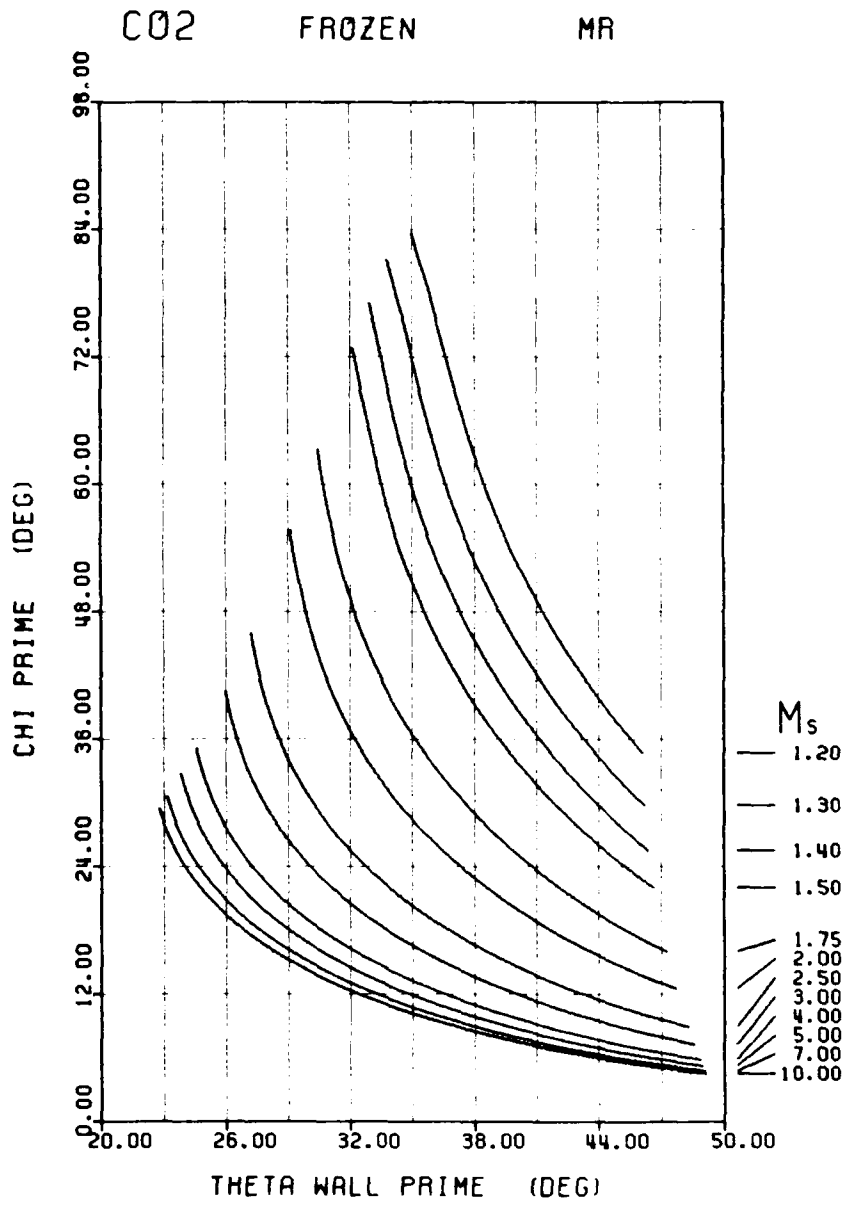

C02 FROZEN MR
PHI3 (DEG)
THETA WALL PRIME (DEG)
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
20.00
26.00
32.00
38.00
44.00
50.00
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms

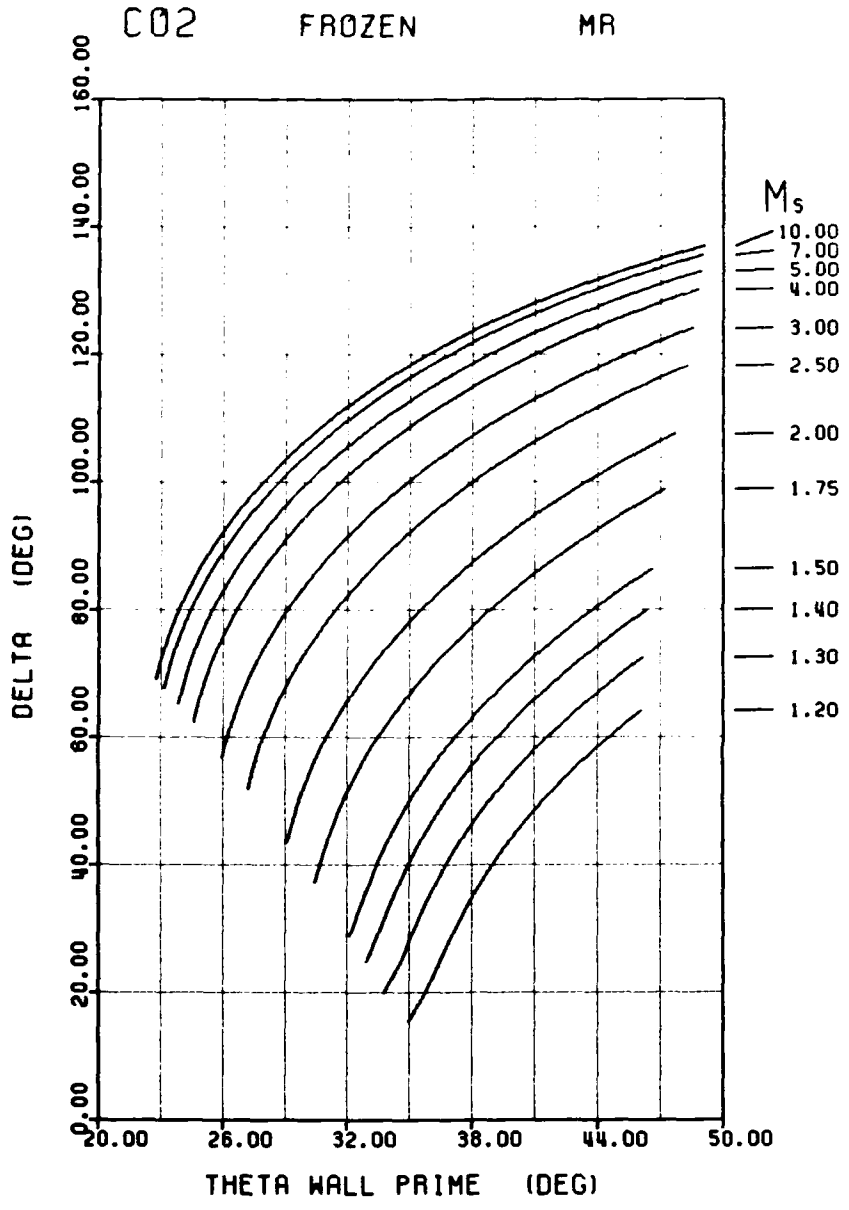

C02 FROZEN MR
THETA1 (DEG)
THETA WALL PRIME (DEG)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
20.00
26.00
32.00
38.00
44.00
50.00
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

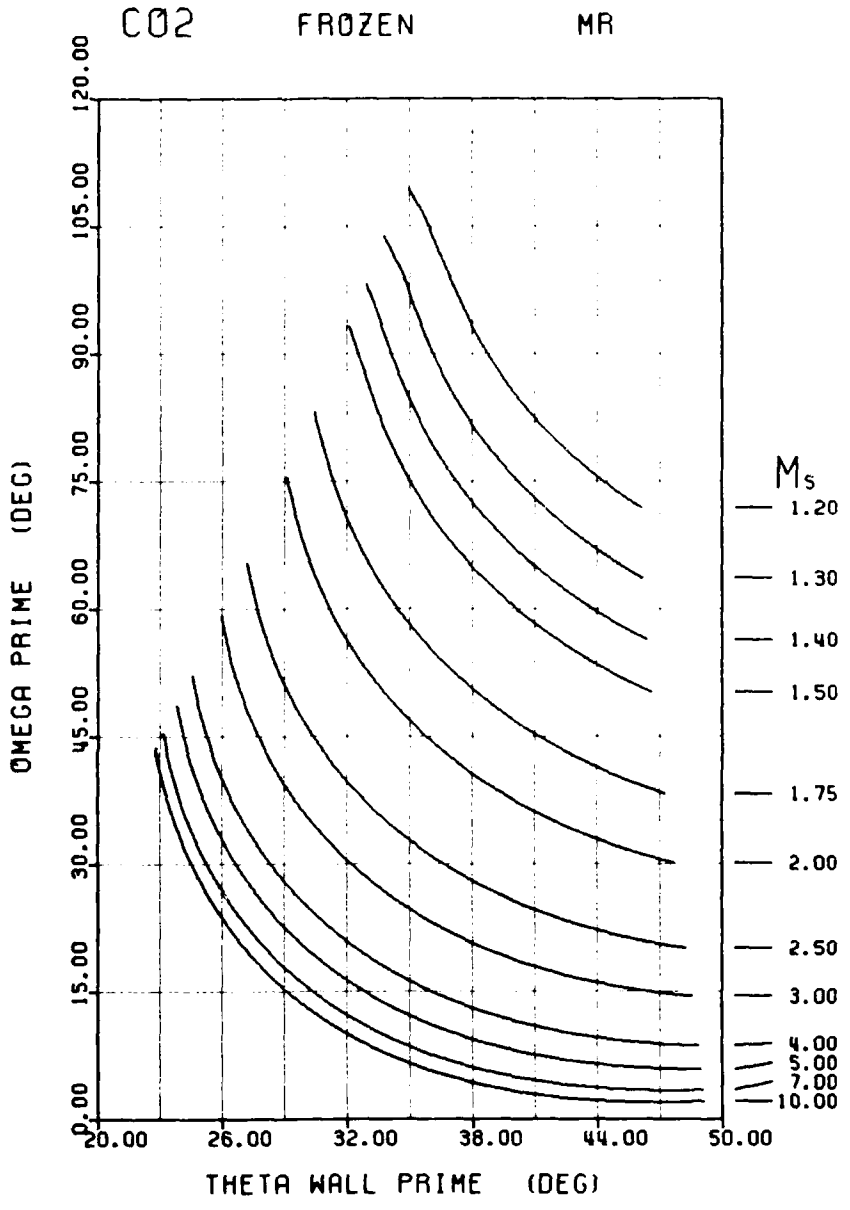

C02 FROZEN MR
THETA2 (DEG)
18.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
Ms
2.00
2.50
3.00
1.75
4.00
5.00
7.00
10.00
1.50
1.40
1.30
1.20

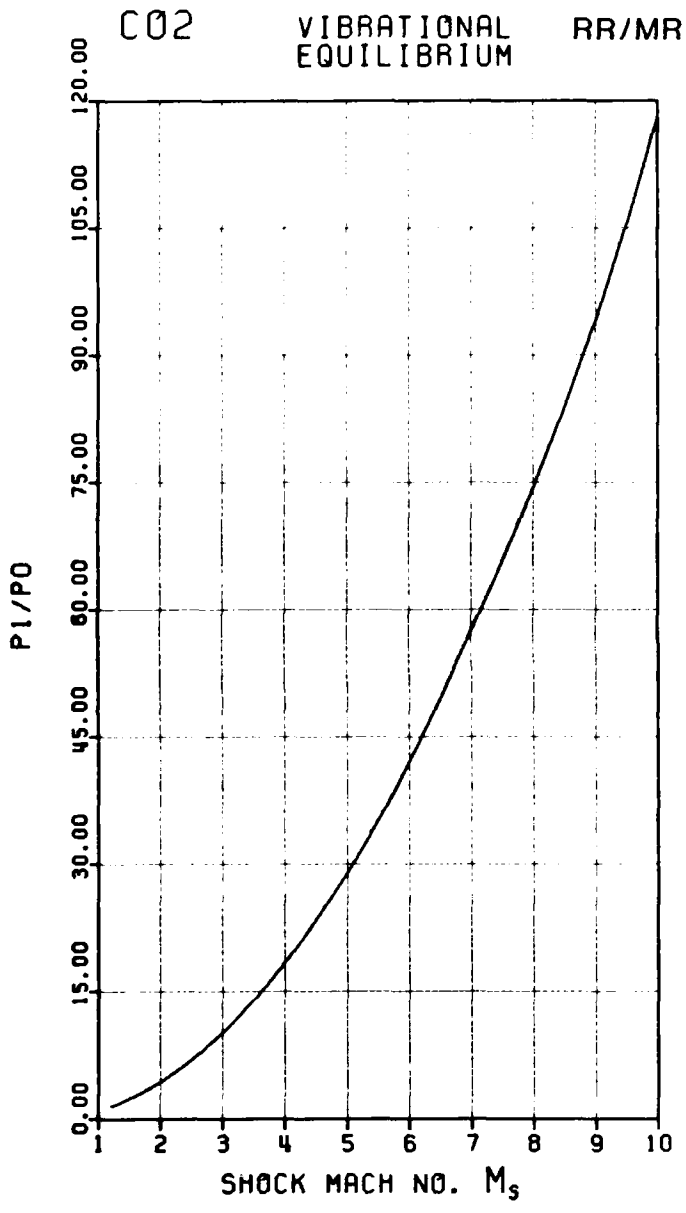

C02 FROZEN MR
THETA3 (DEG)
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
0.00
20.00
26.00
32.00
38.00
44.00
50.00
THETA WALL PRIME (DEG)
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms

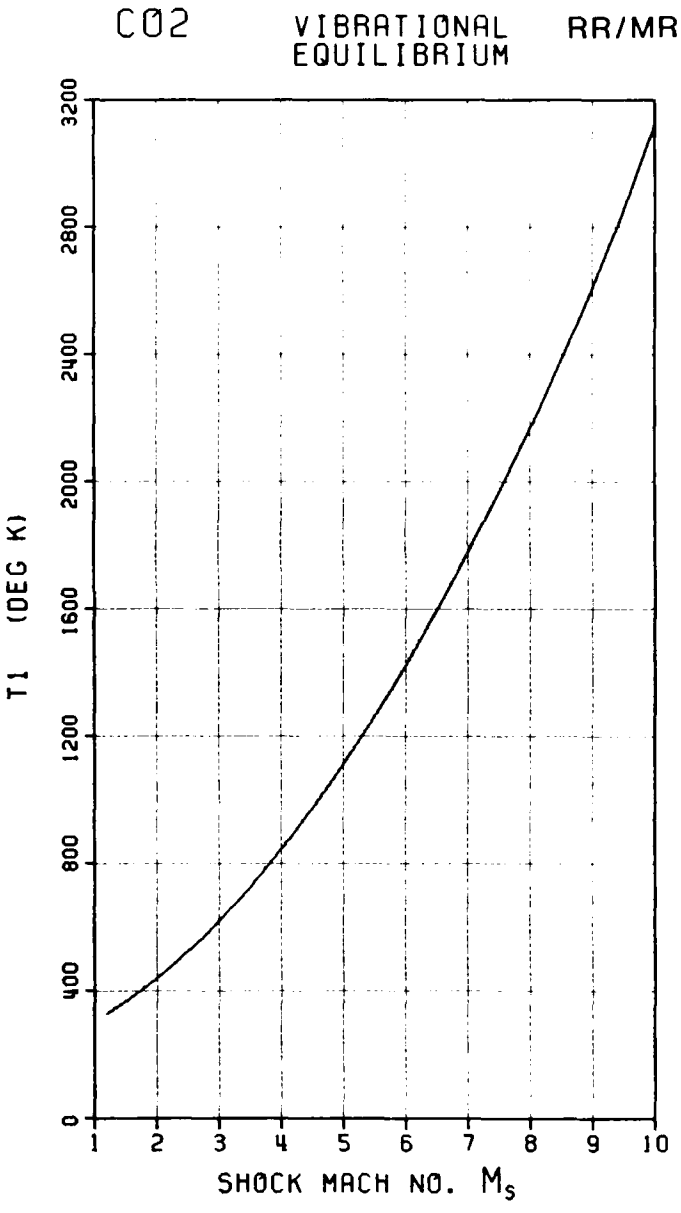

C02 FROZEN MR
CHI (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
20.00
26.00
32.00
38.00
44.00
50.00

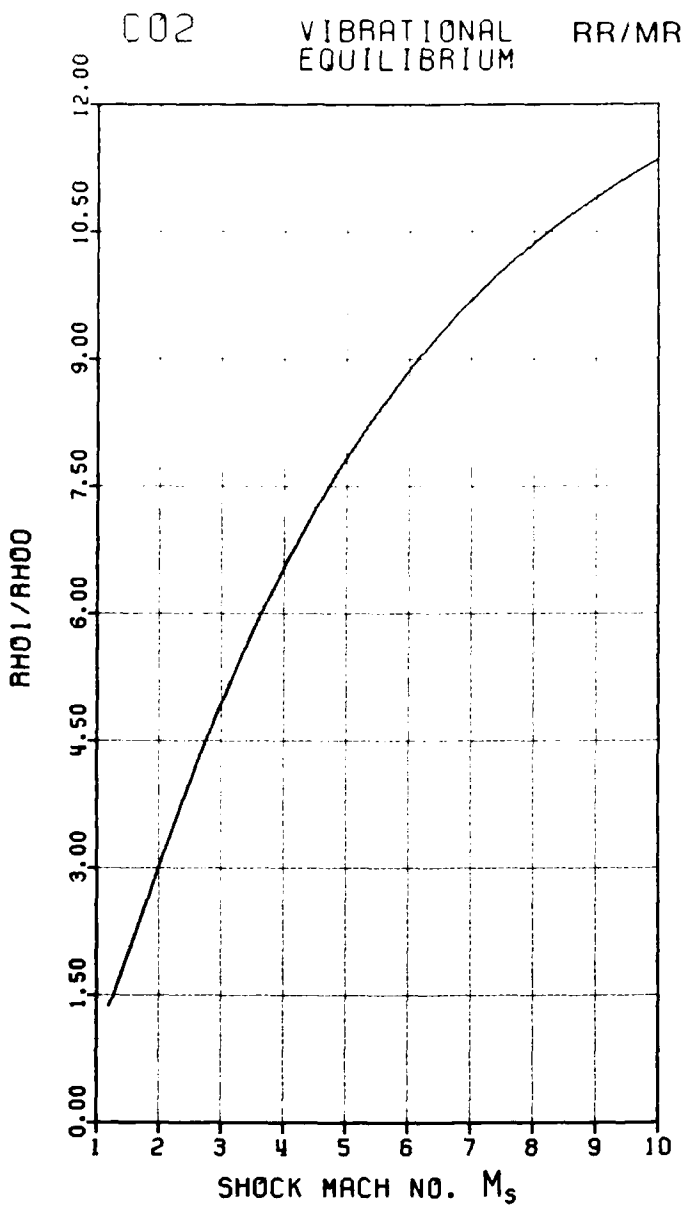

C02 FROZEN MR
CHI PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
20.00
26.00
32.00
38.00
44.00
50.00

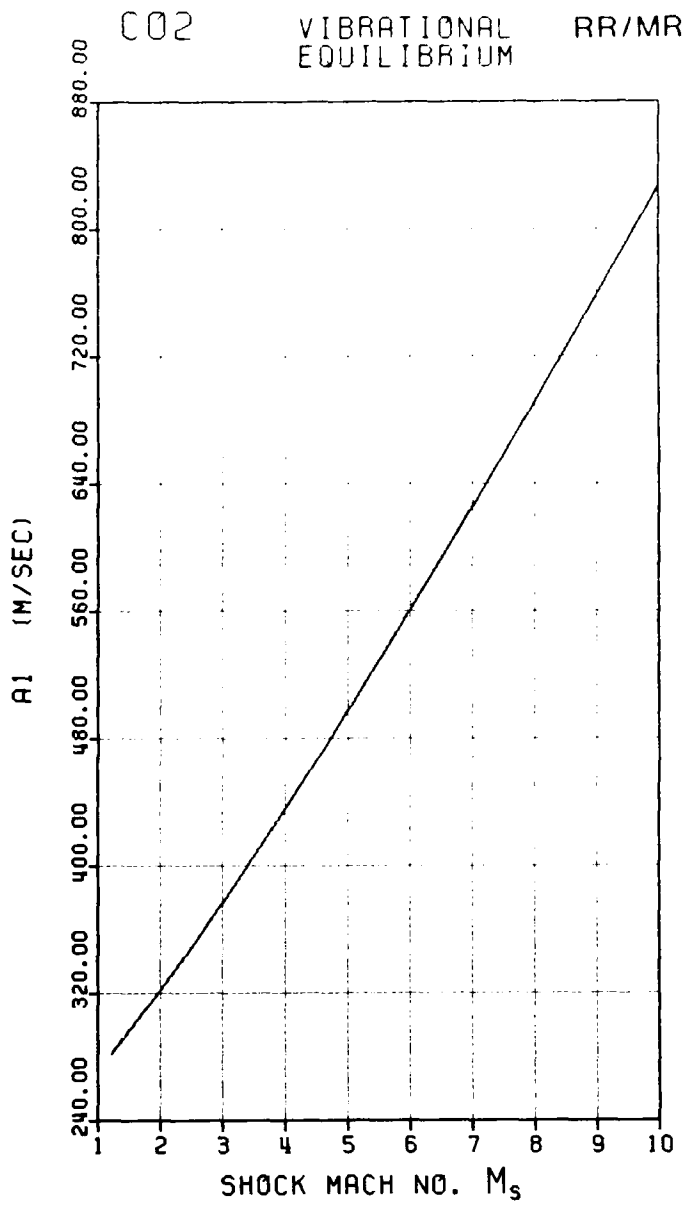

C02 FROZEN MR
DELTA (DEG)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
20.00
26.00
32.00
38.00
44.00
50.00

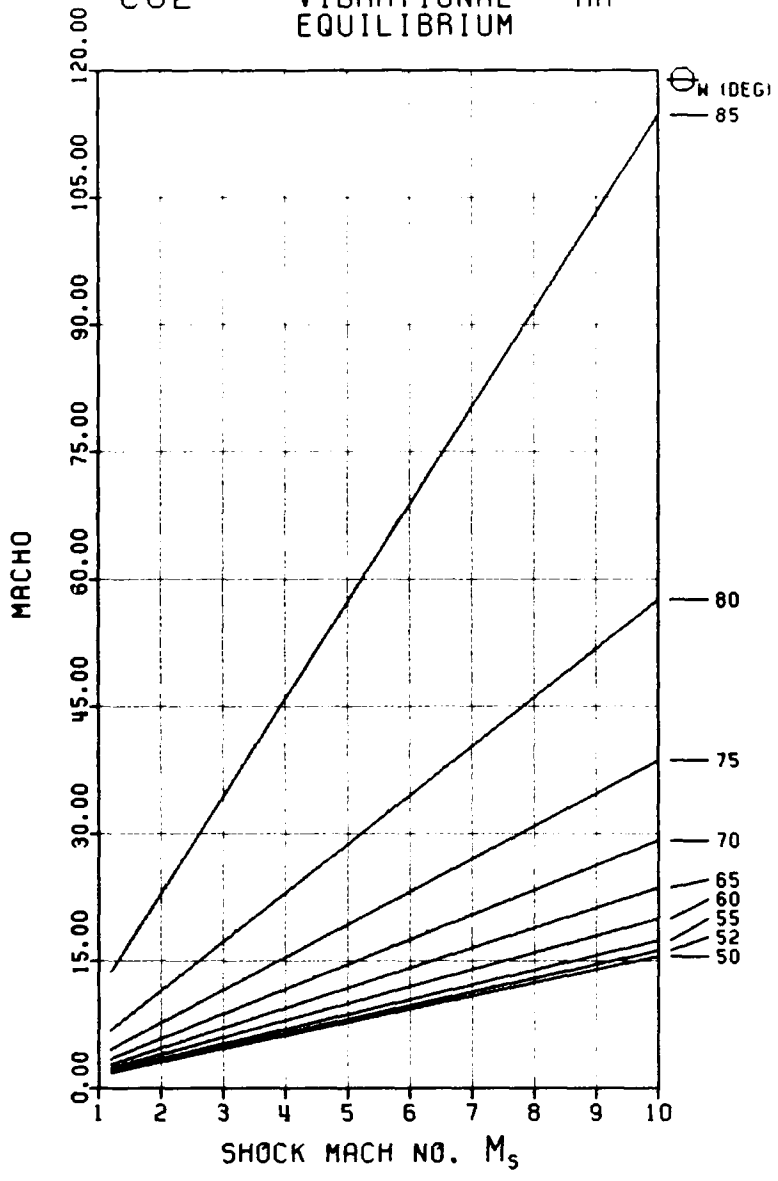

C02 FROZEN MR
OMEGA PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
20.00
26.00
32.00
38.00
44.00
50.00

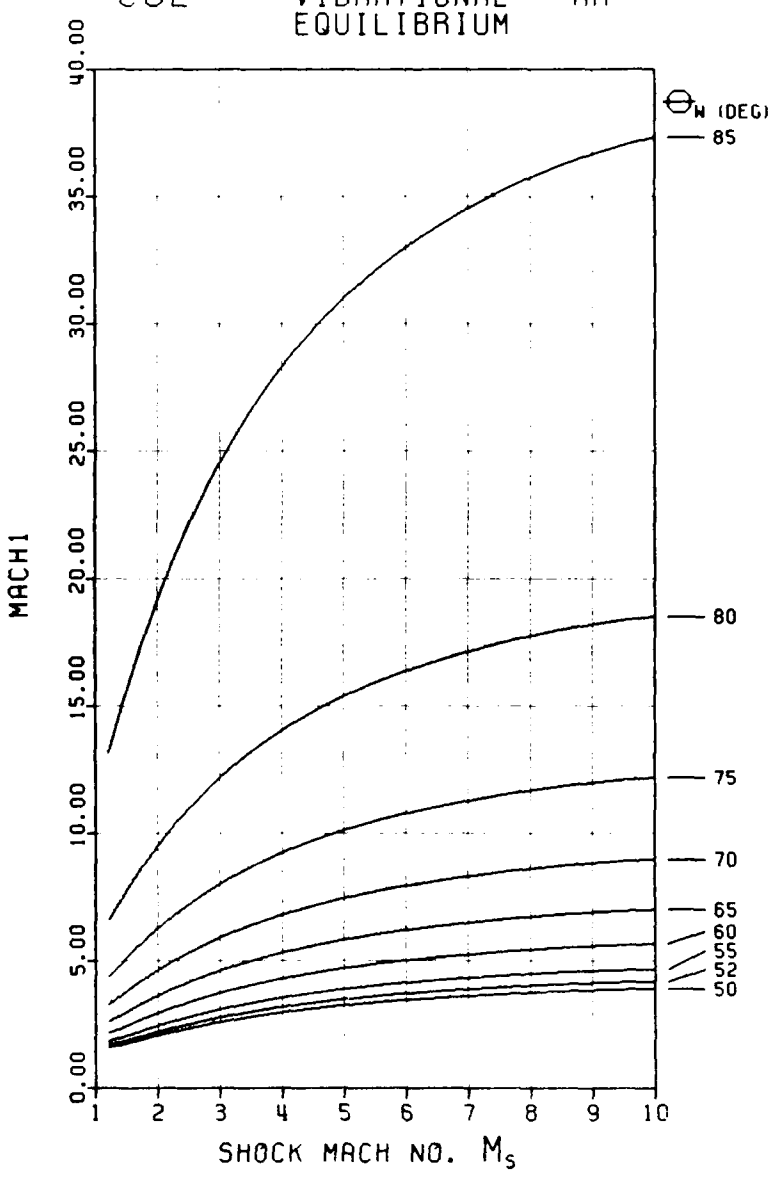

C02 VIBRATIONAL EQUILIBRIUM RR/MR
P1/P0
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s

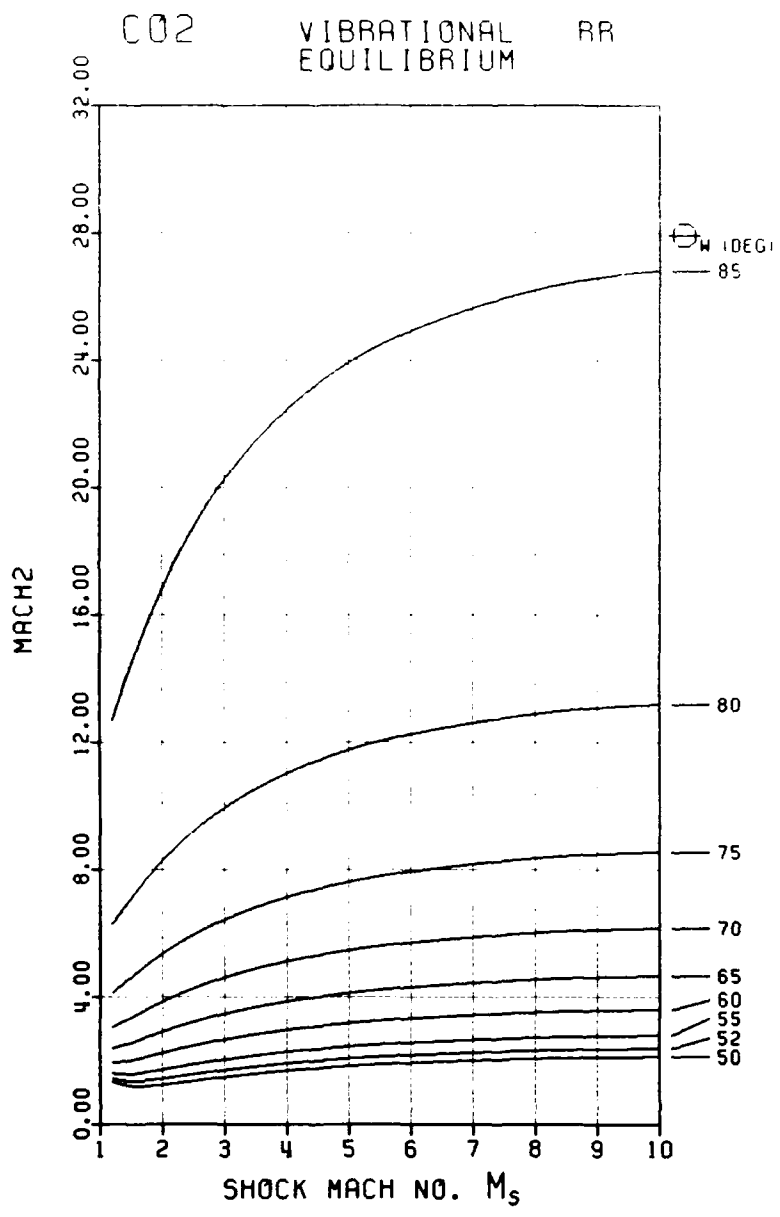

C02 VIBRATIONAL EQUILIBRIUM RR/MR
T1 (DEG K)
0
400
800
1200
1600
2000
2400
2800
3200
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s

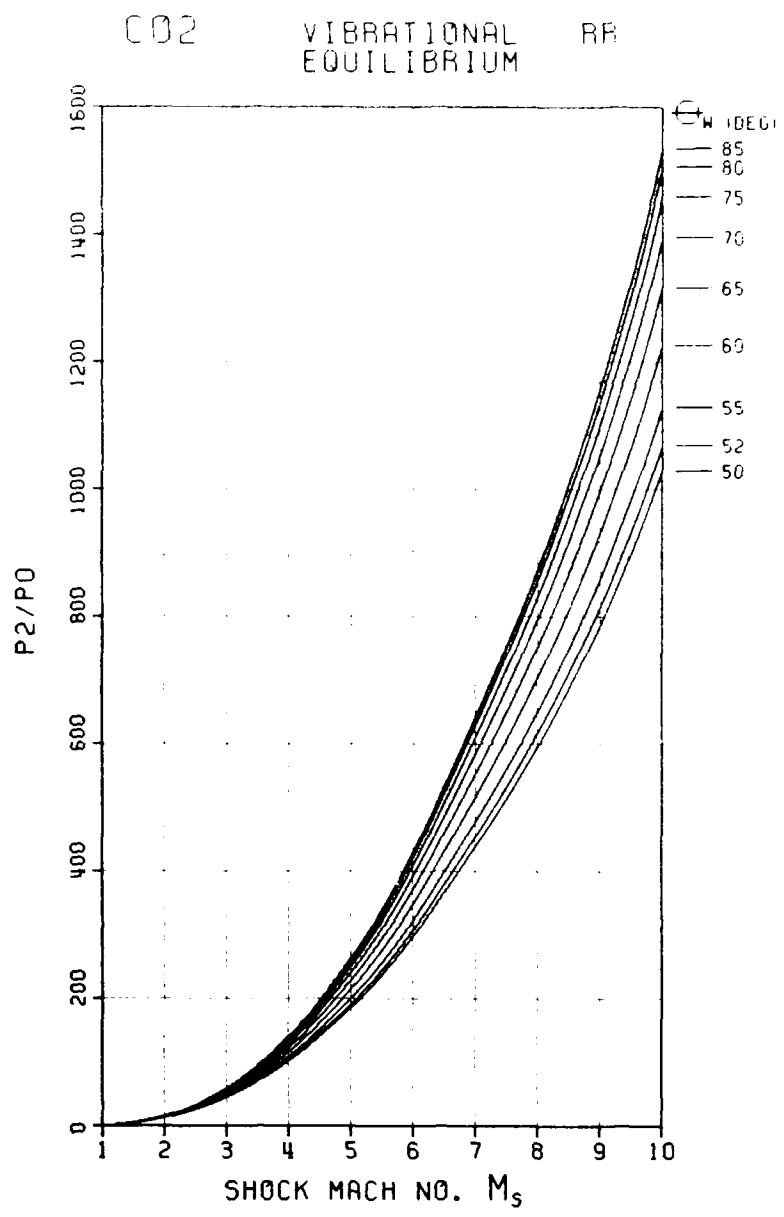

CO2 VIBRATIONAL EQUILIBRIUM RR/MR
RHO1/RHOO
0.00
1.50
3.00
4.50
6.00
7.50
9.00
10.50
12.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

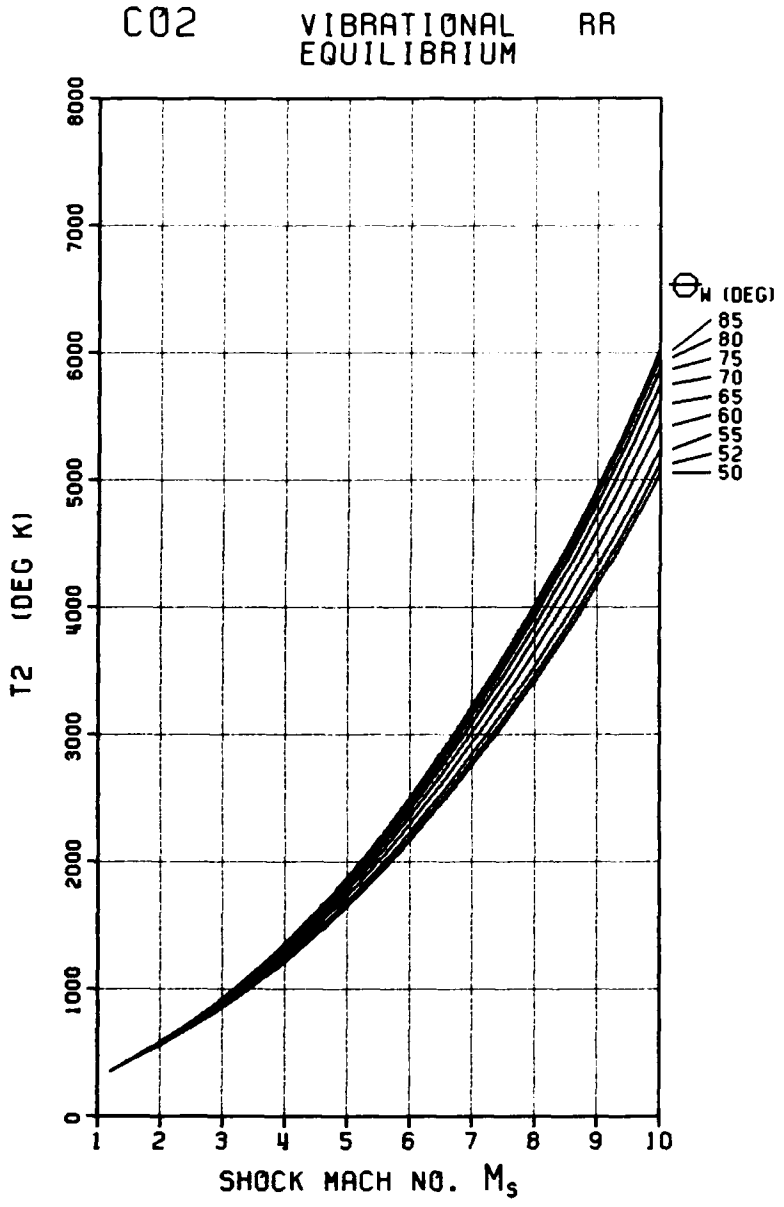

CO2 VIBRATIONAL EQUILIBRIUM RR/MR
A1 (M/SEC)
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
880.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

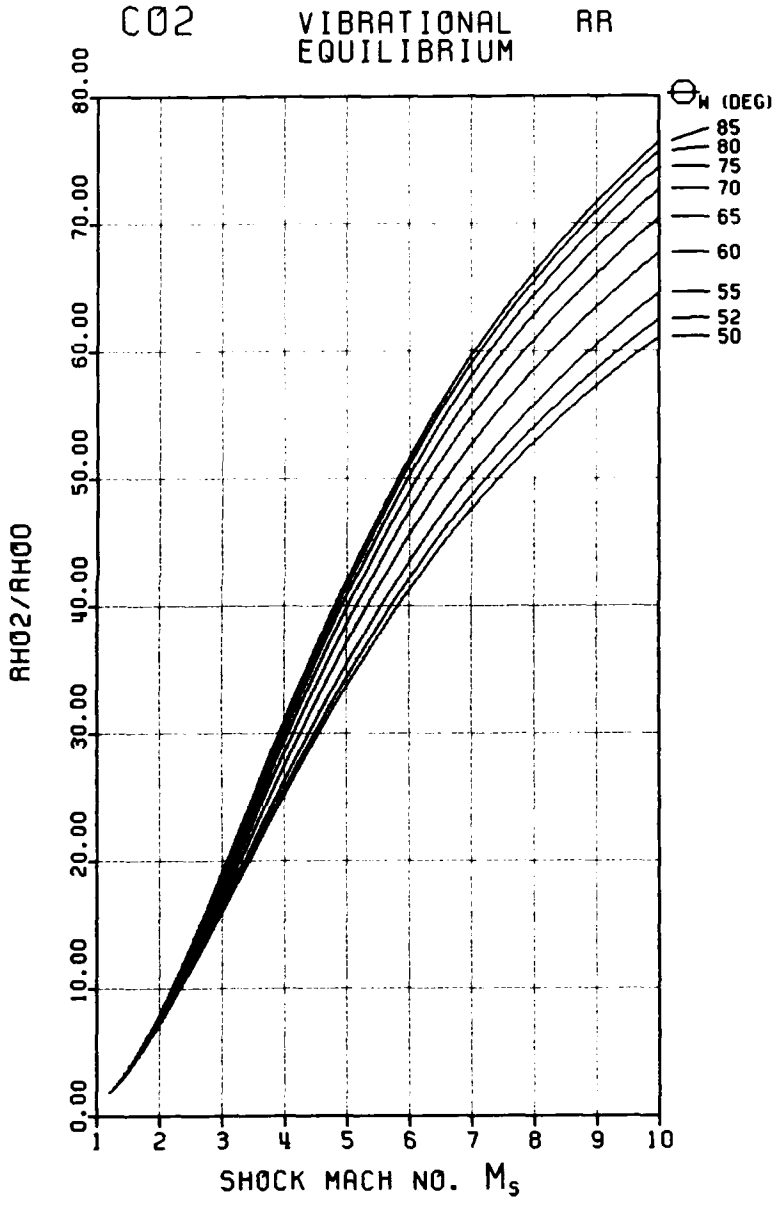

C02 VIBRATIONAL EQUILIBRIUM RR
MACH0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1
2
3
4
5
6
7
8
9
10

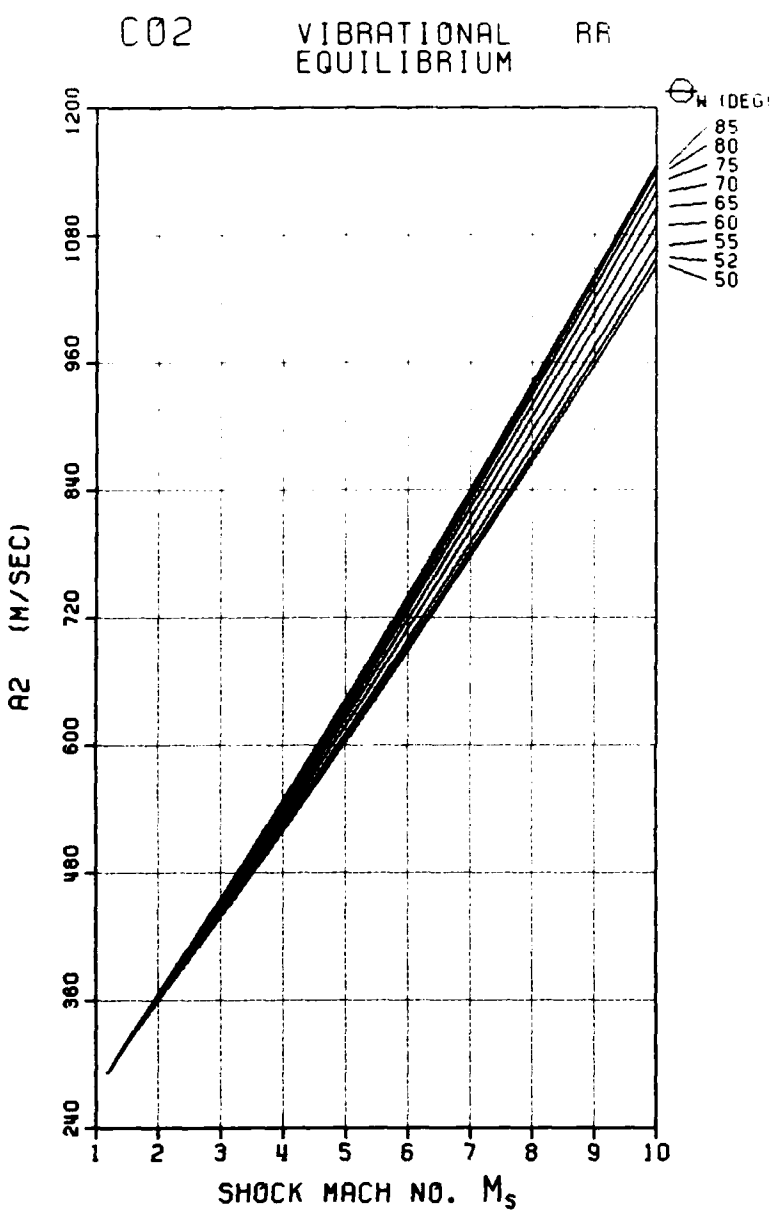

C02 VIBRATIONAL EQUILIBRIUM RR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1
2
3
4
5
6
7
8
9
10

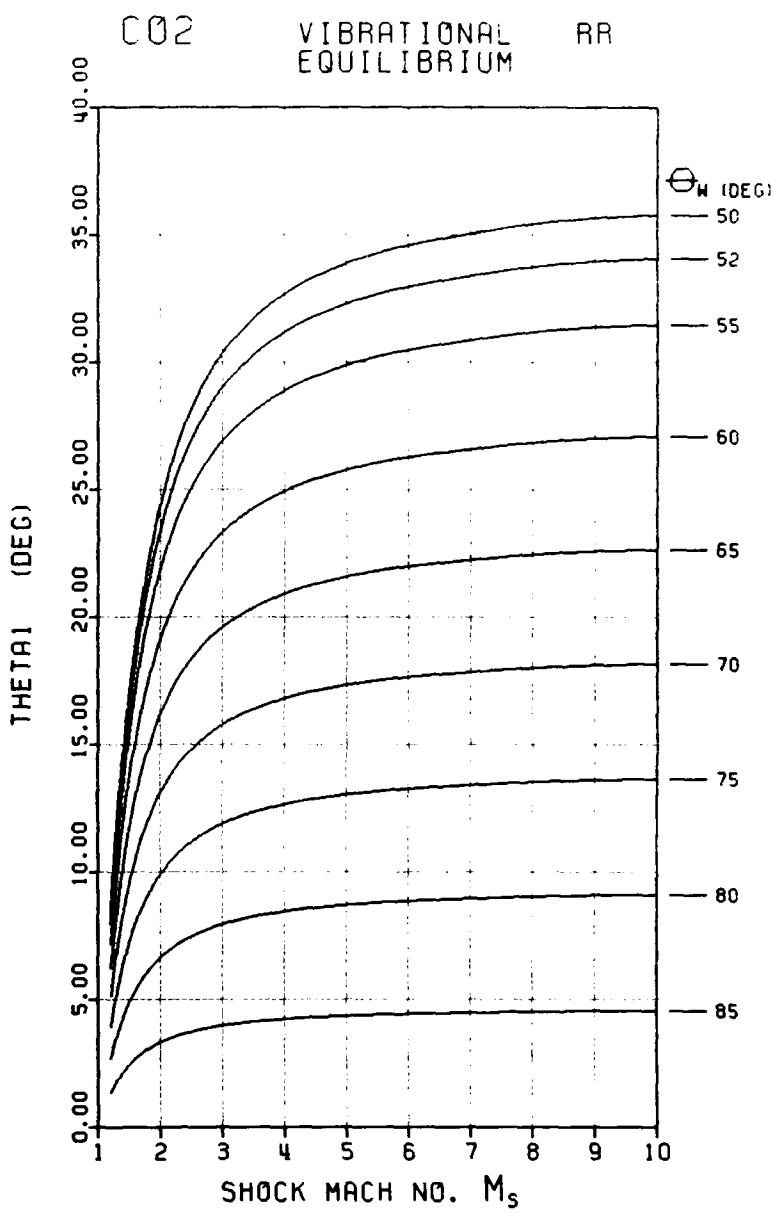

CO2 VIBRATIONAL EQUILIBRIUM RR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
1
2
3
4
5
6
7
8
9
10

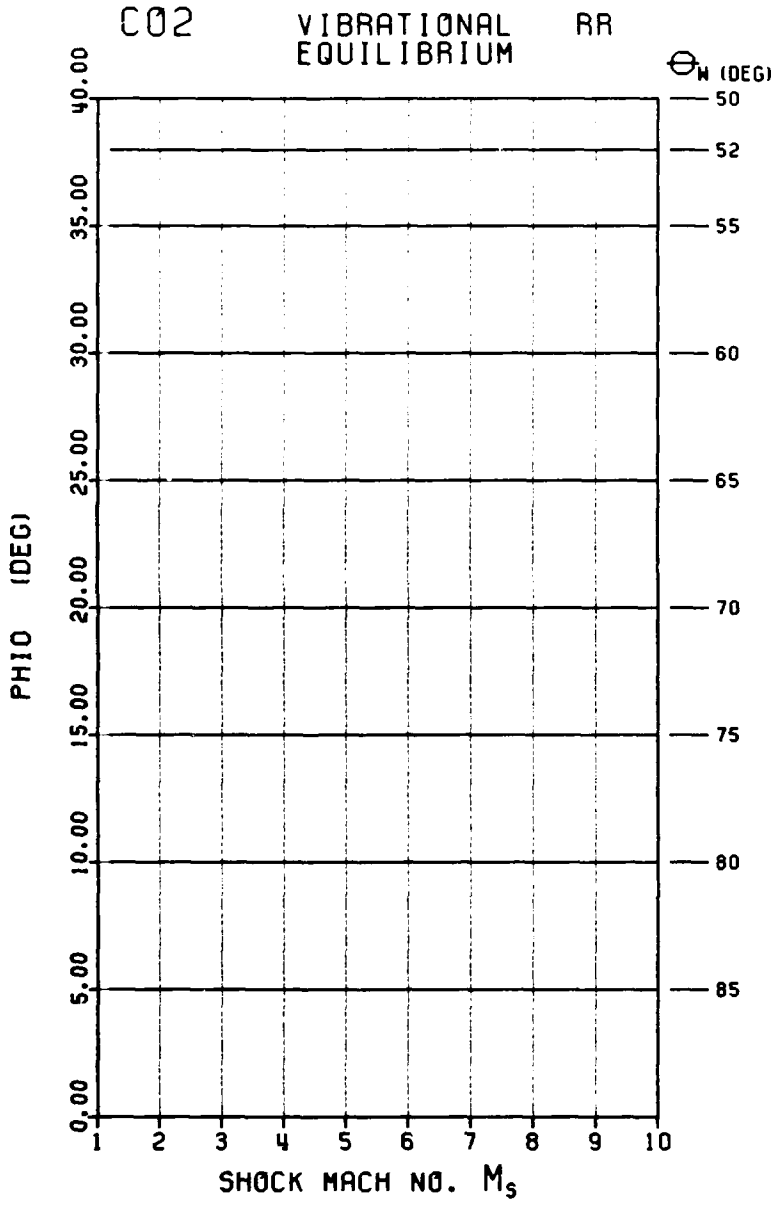

CO2 VIBRATIONAL EQUILIBRIUM RR
P2/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50
0
200
400
600
800
1000
1200
1400
1600
1
2
3
4
5
6
7
8
9
10

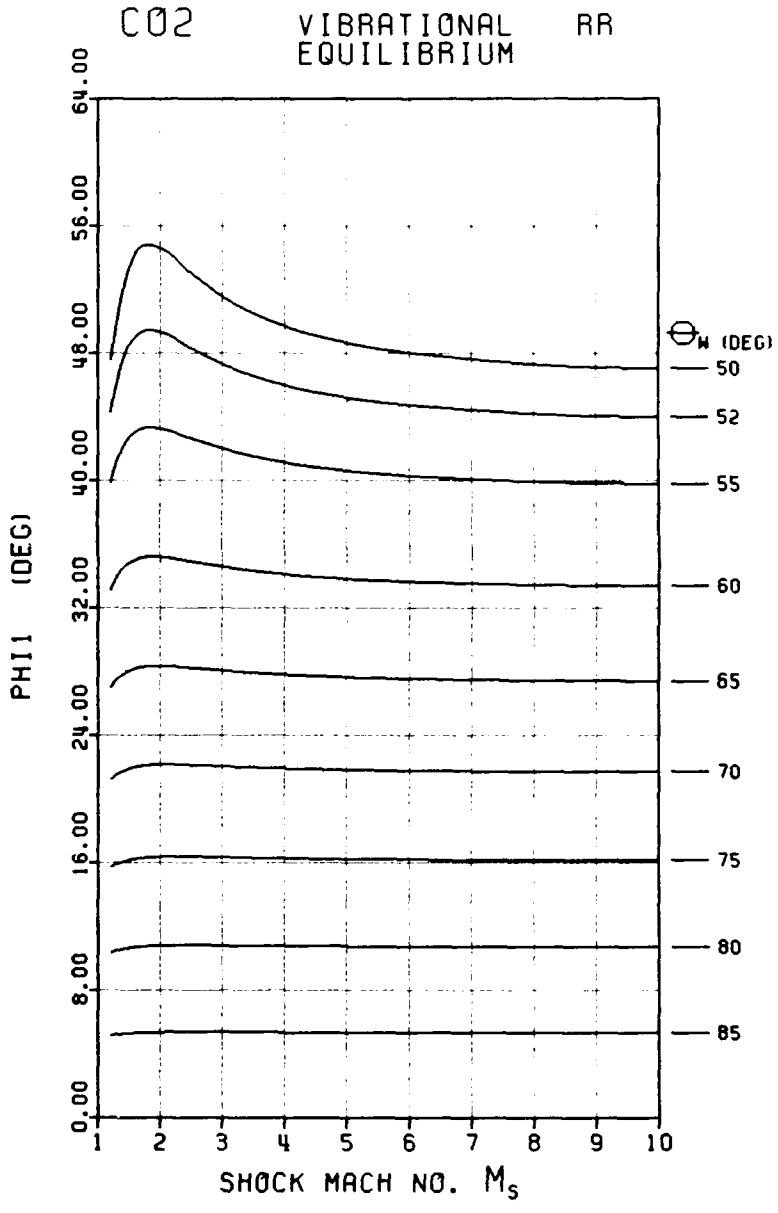

C02 VIBRATIONAL EQUILIBRIUM RR
T2 (DEG K)
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50

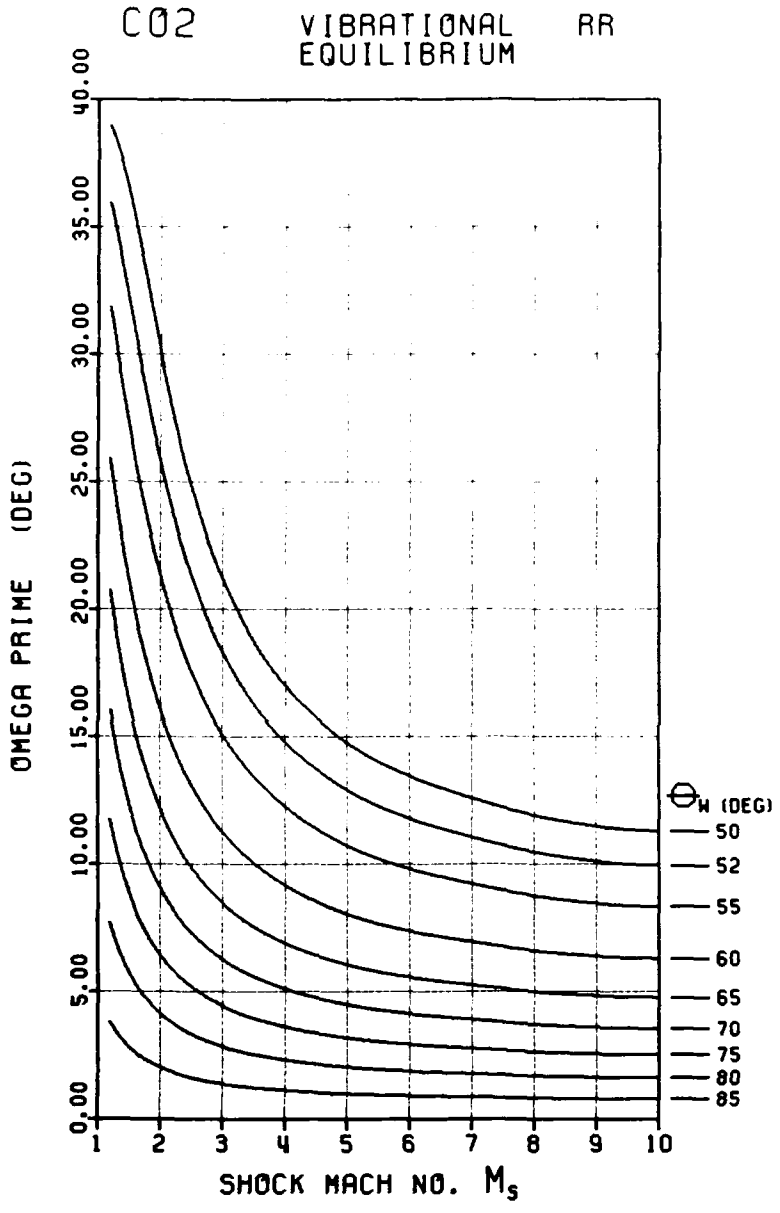

C02 VIBRATIONAL EQUILIBRIUM RR
RH02/RH00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
52
50

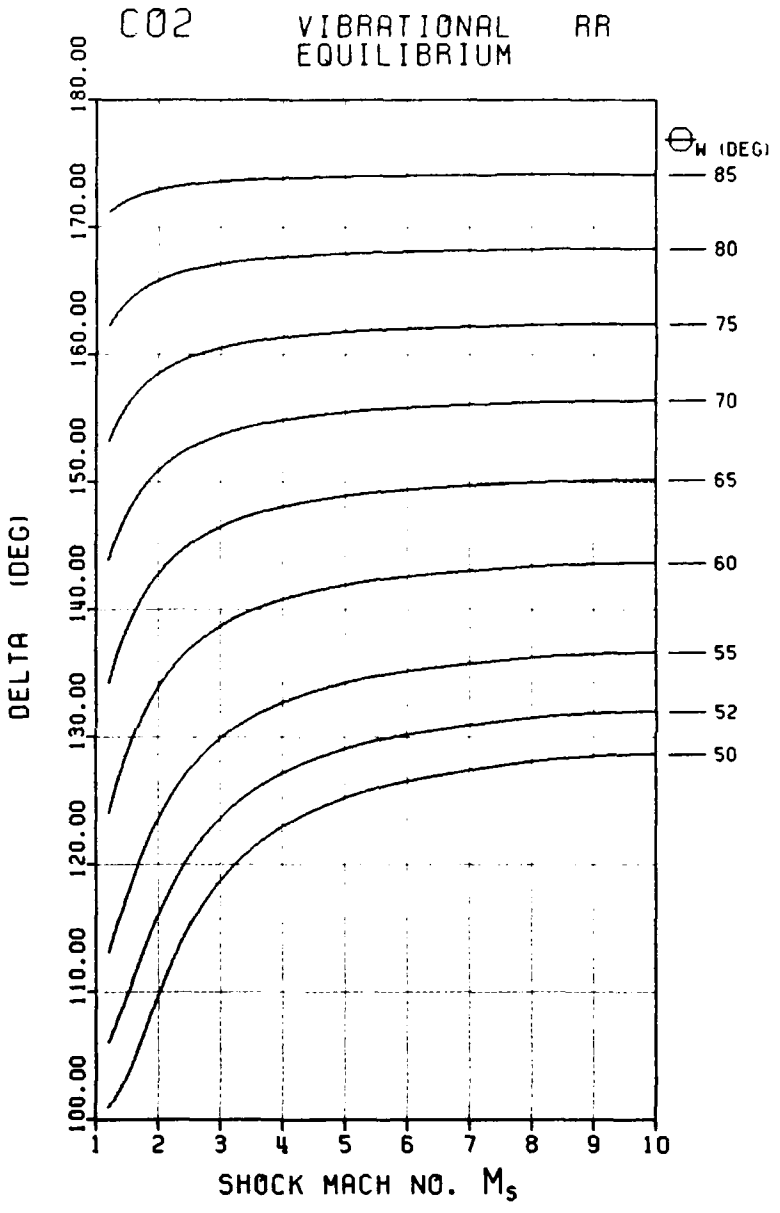

C02 VIBRATIONAL EQUILIBRIUM RR
Θ_W (DEG)
85
80
75
70
65
60
55
52
50
A2 (M/SEC)
240
360
480
600
720
840
960
1080
1200
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

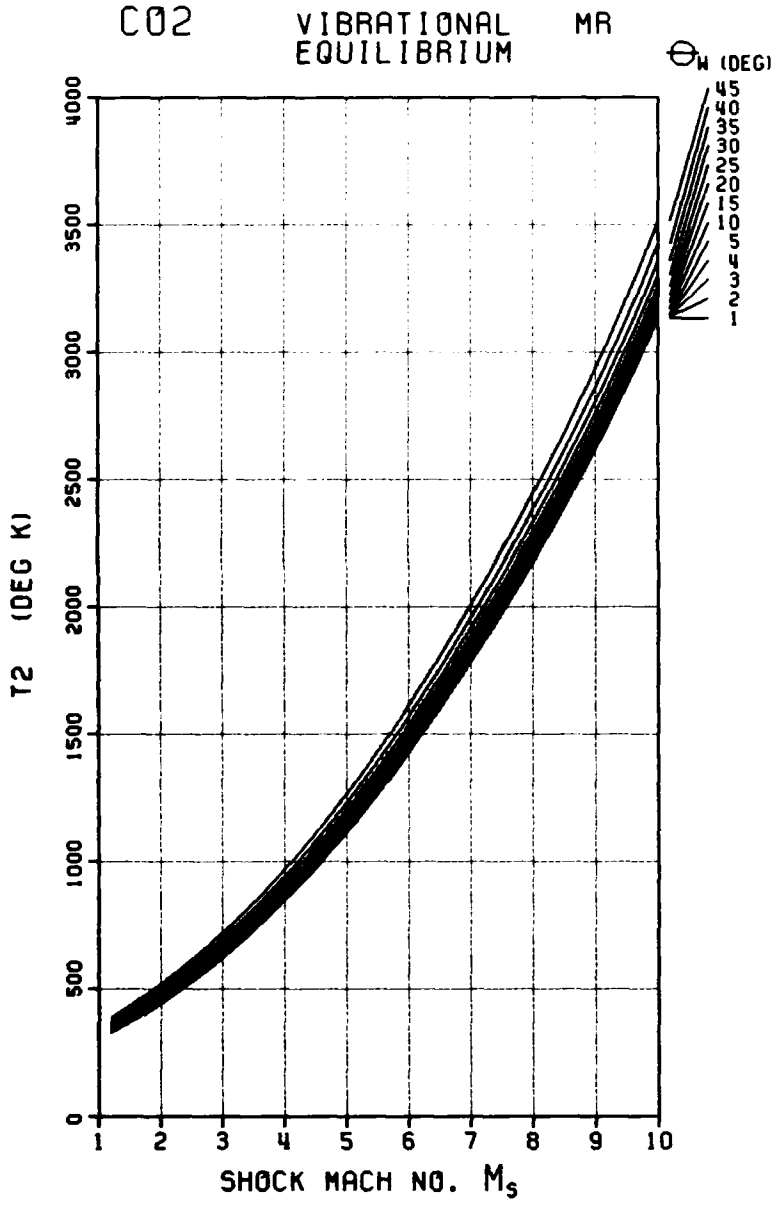

C02 VIBRATIONAL EQUILIBRIUM RR
Θ_W (DEG)
50
52
55
60
65
70
75
80
85
THETA1 (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

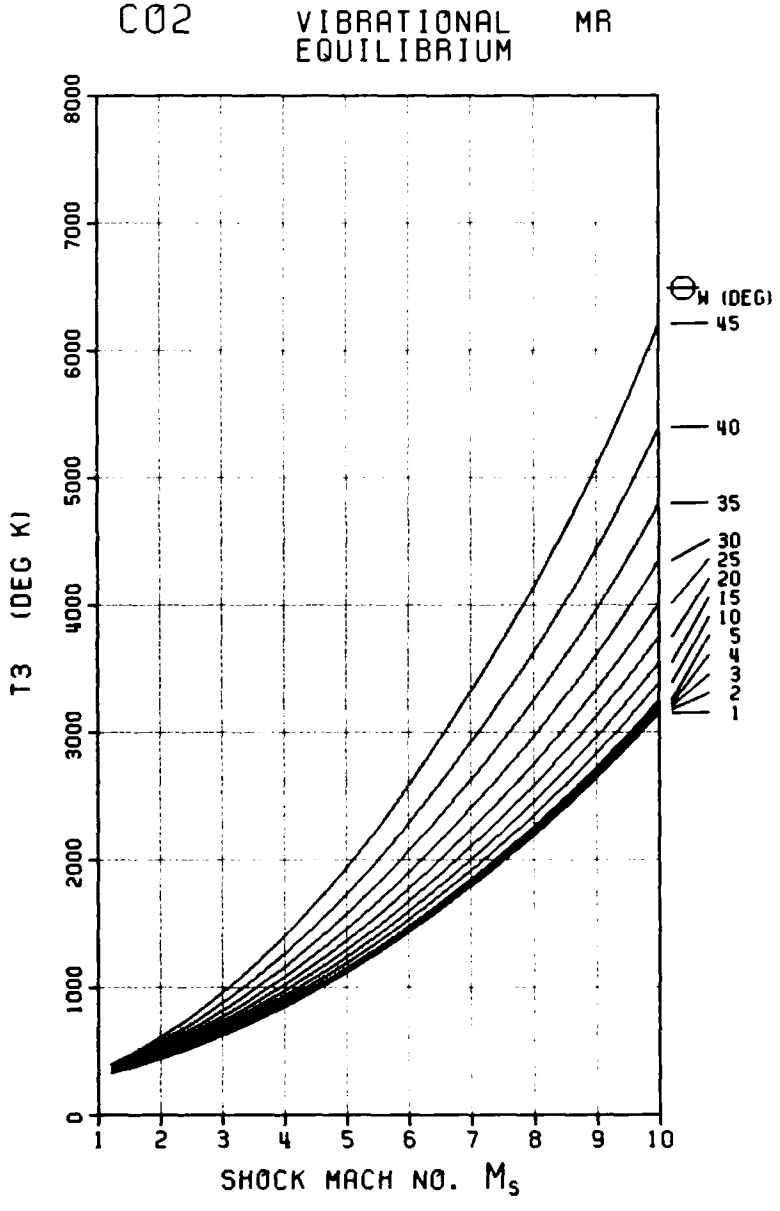

C02 VIBRATIONAL EQUILIBRIUM RR
Θ_W (DEG)
50
52
55
60
65
70
75
80
85
PHI0 (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

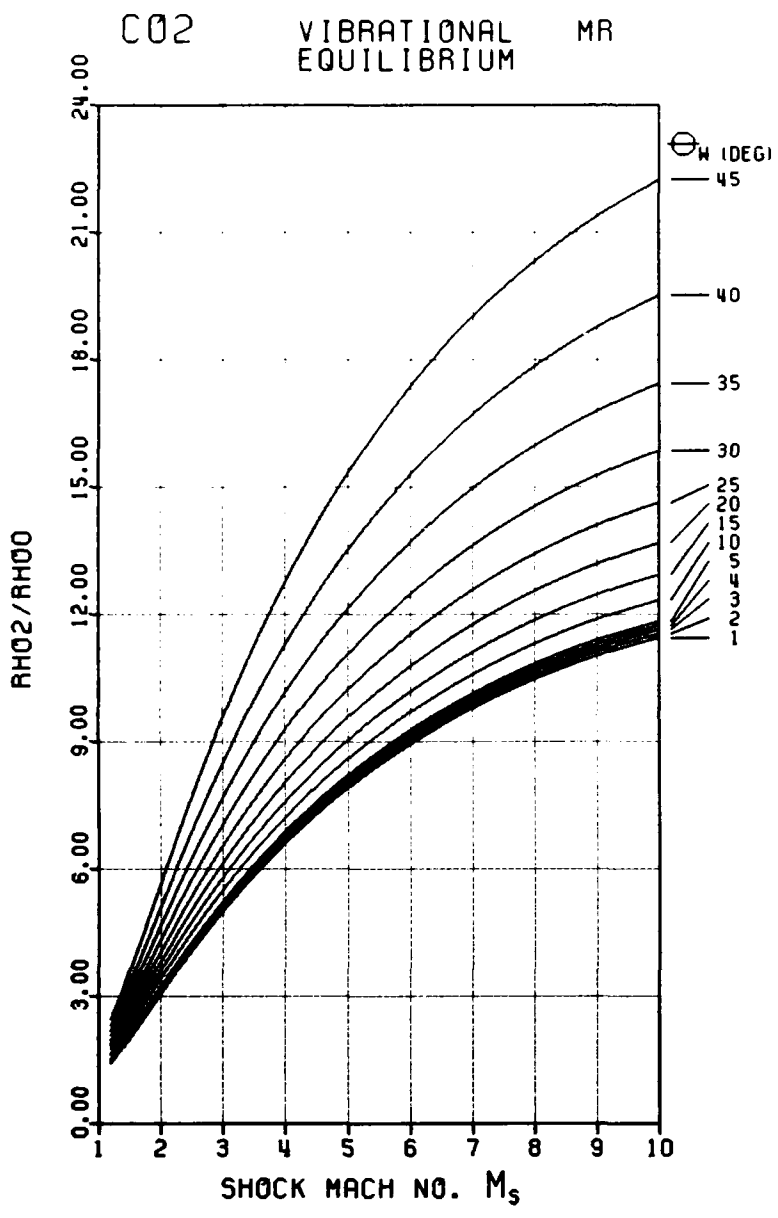

C02 VIBRATIONAL EQUILIBRIUM RR
Θ_W (DEG)
50
52
55
60
65
70
75
80
85
PHI1 (DEG)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

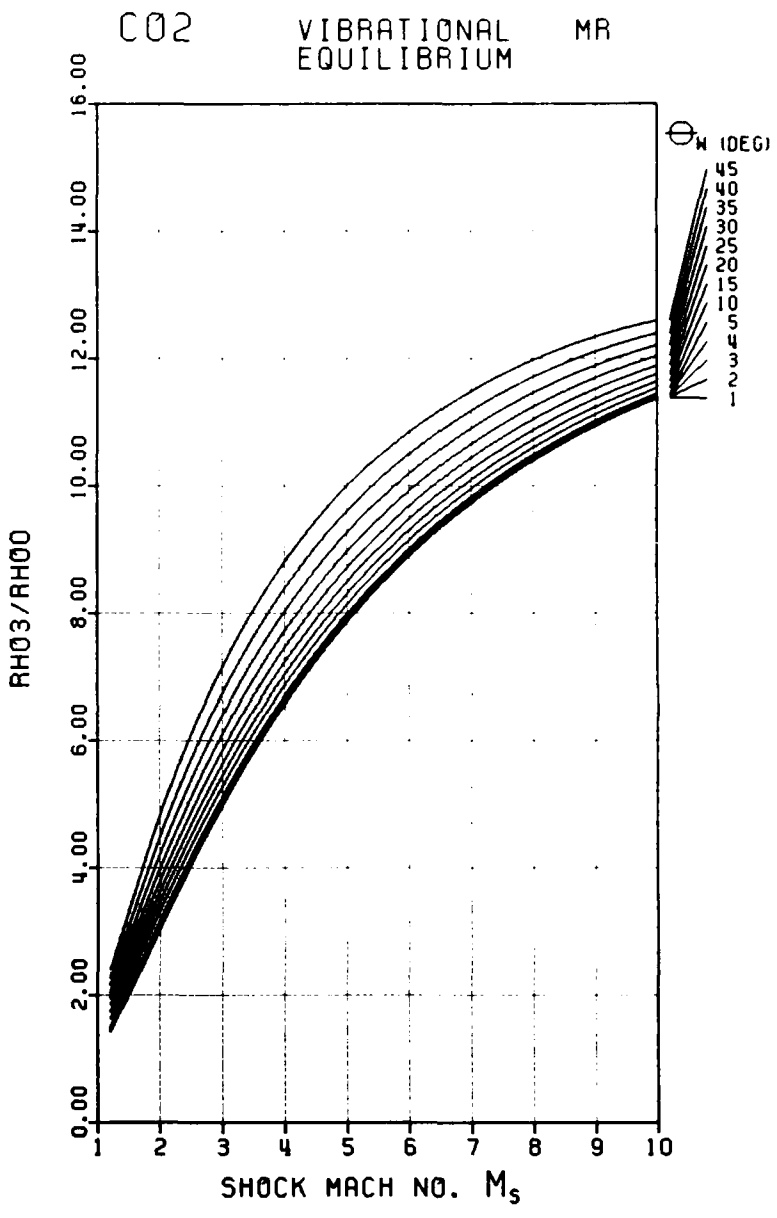

CO2 VIBRATIONAL EQUILIBRIUM RR
OMEGA PRIME (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
50
52
55
60
65
70
75
80
85

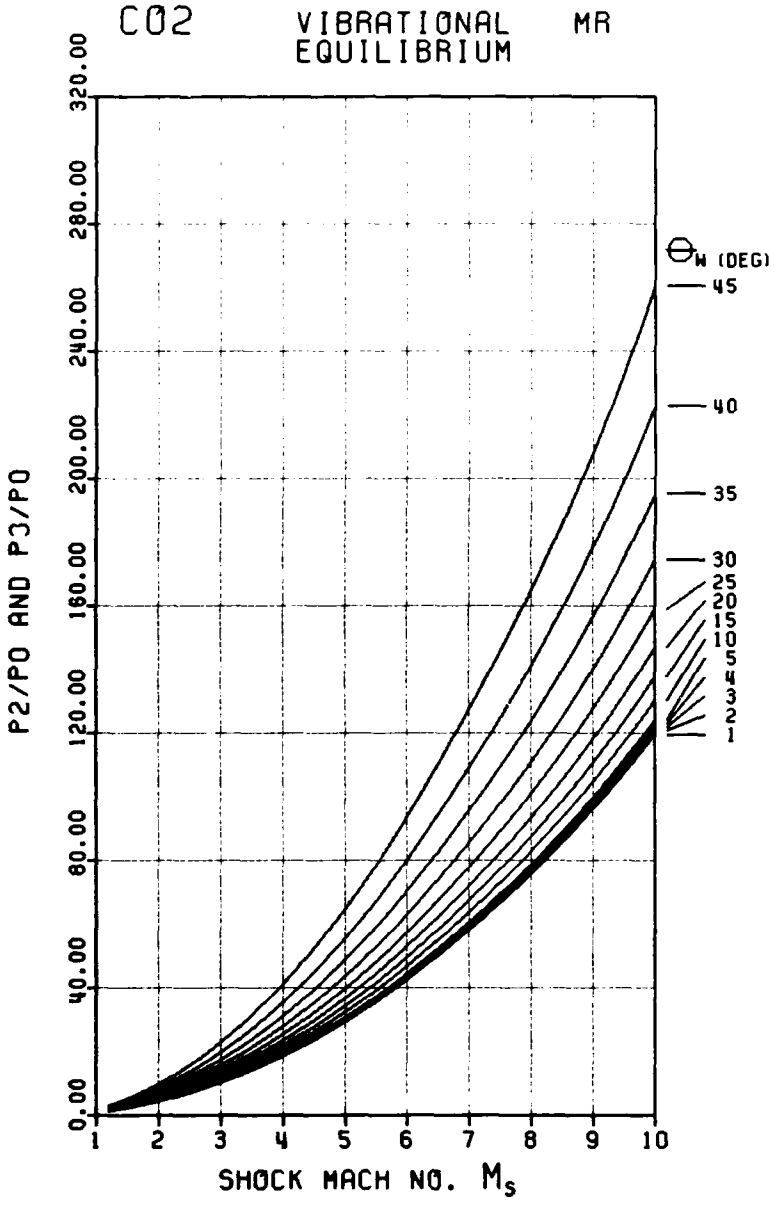

CO2 VIBRATIONAL EQUILIBRIUM RR
DELTA (DEG)
100.00
110.00
120.00
130.00
140.00
150.00
160.00
170.00
180.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
85
80
75
70
65
60
55
52
50

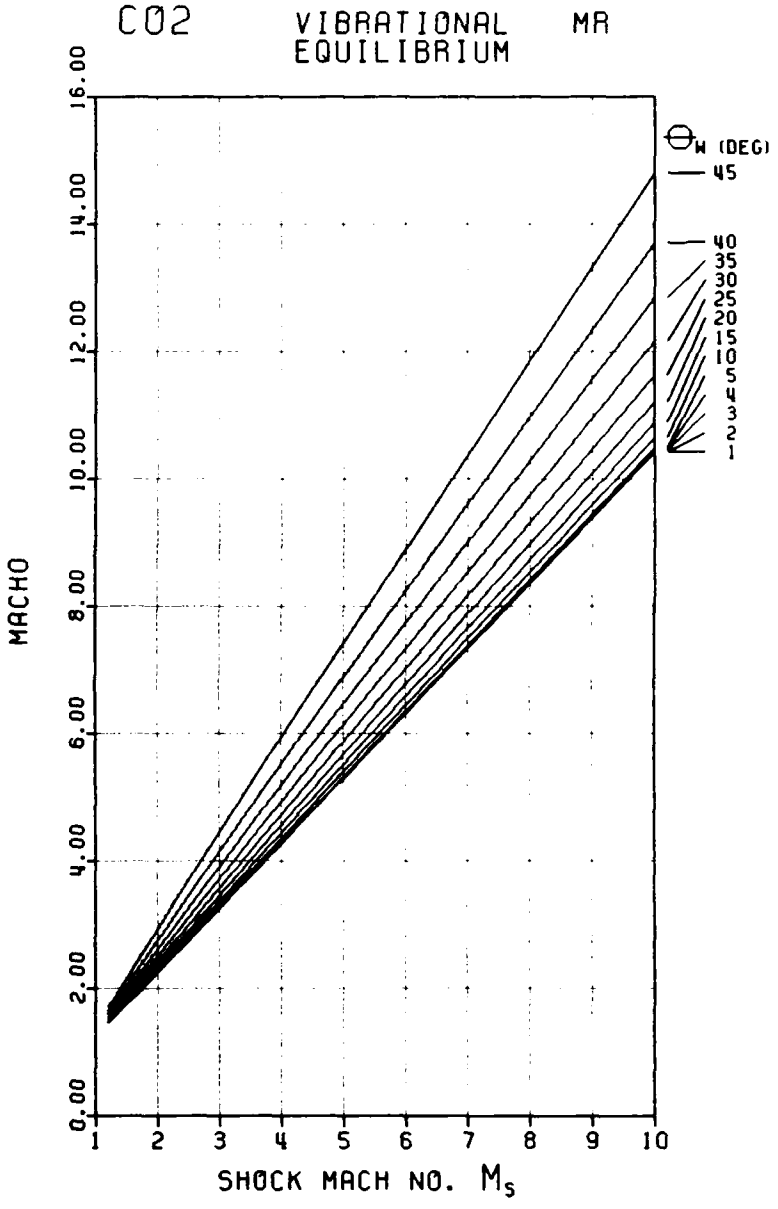

C02
VIBRATIONAL EQUILIBRIUM
MR
θW (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
T2 (DEG K)
0
500
1000
1500
2000
2500
3000
3500
4000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. MS

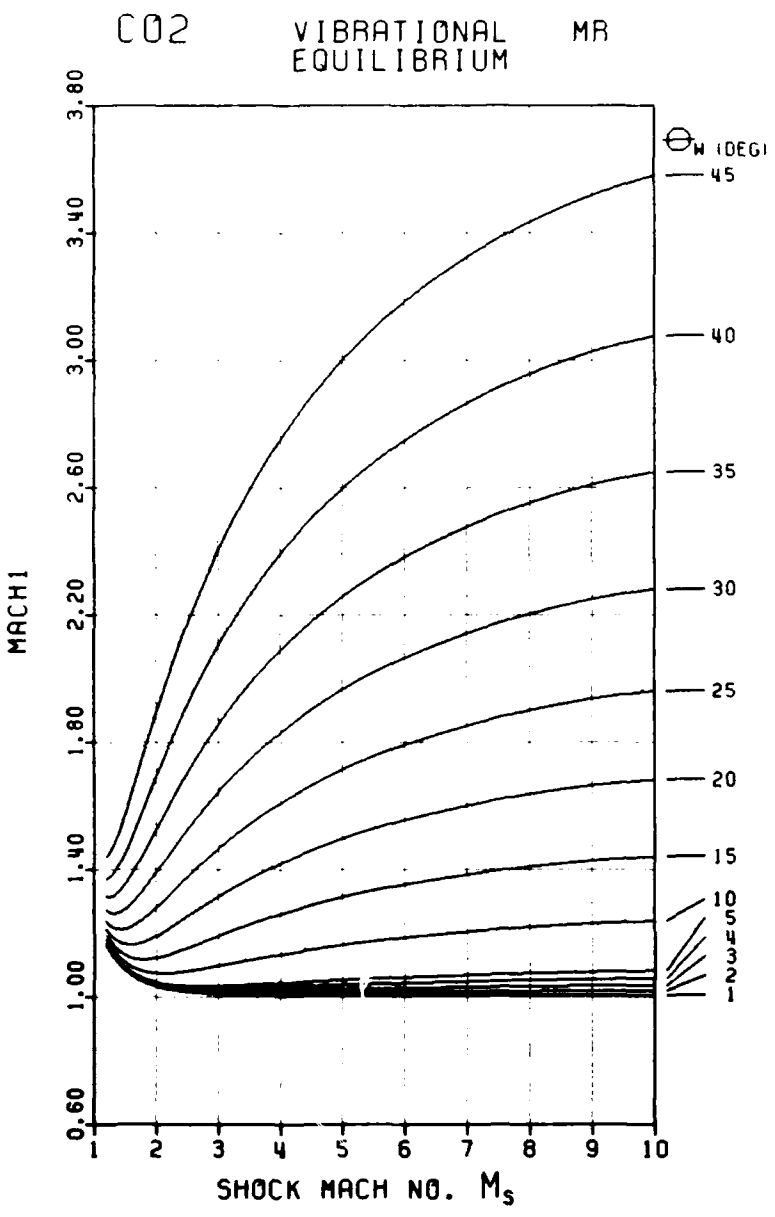

C02
VIBRATIONAL EQUILIBRIUM
MR
θW (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
T3 (DEG K)
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. MS

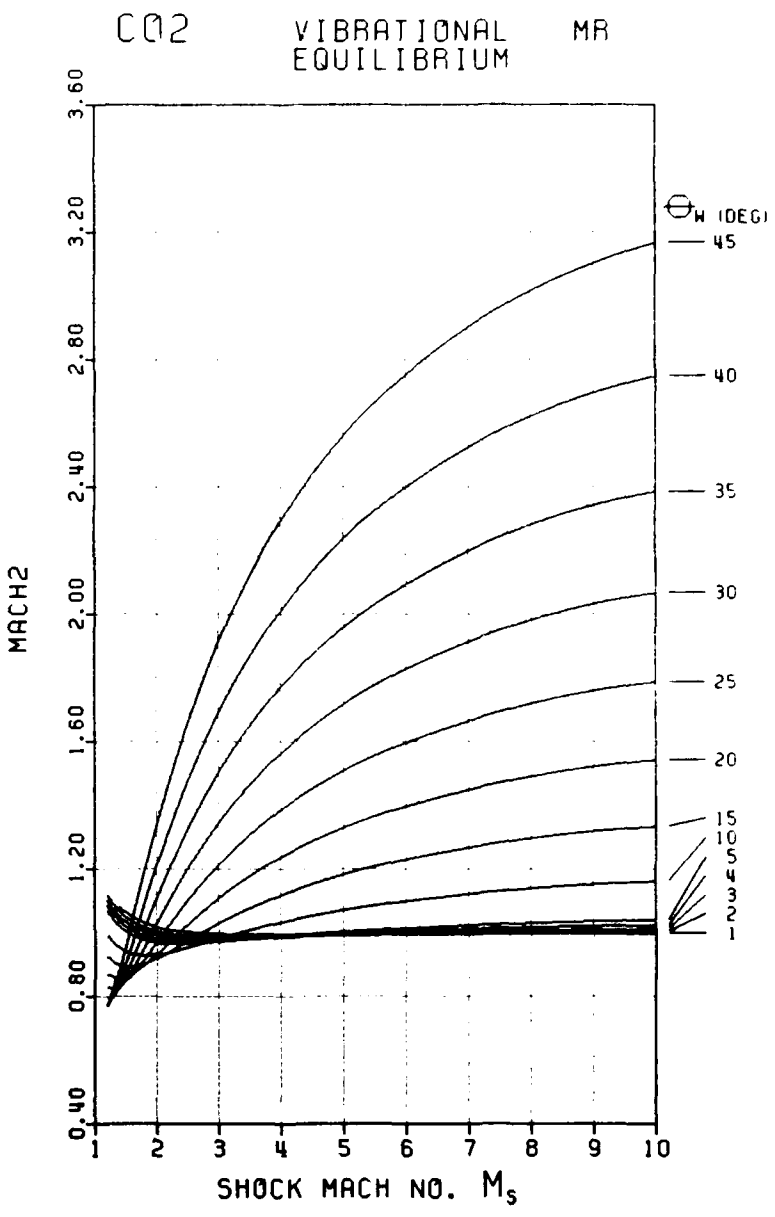

C02 VIBRATIONAL EQUILIBRIUM MR
RH02/RH00
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
1
2
3
4
5
6
7
8
9
10

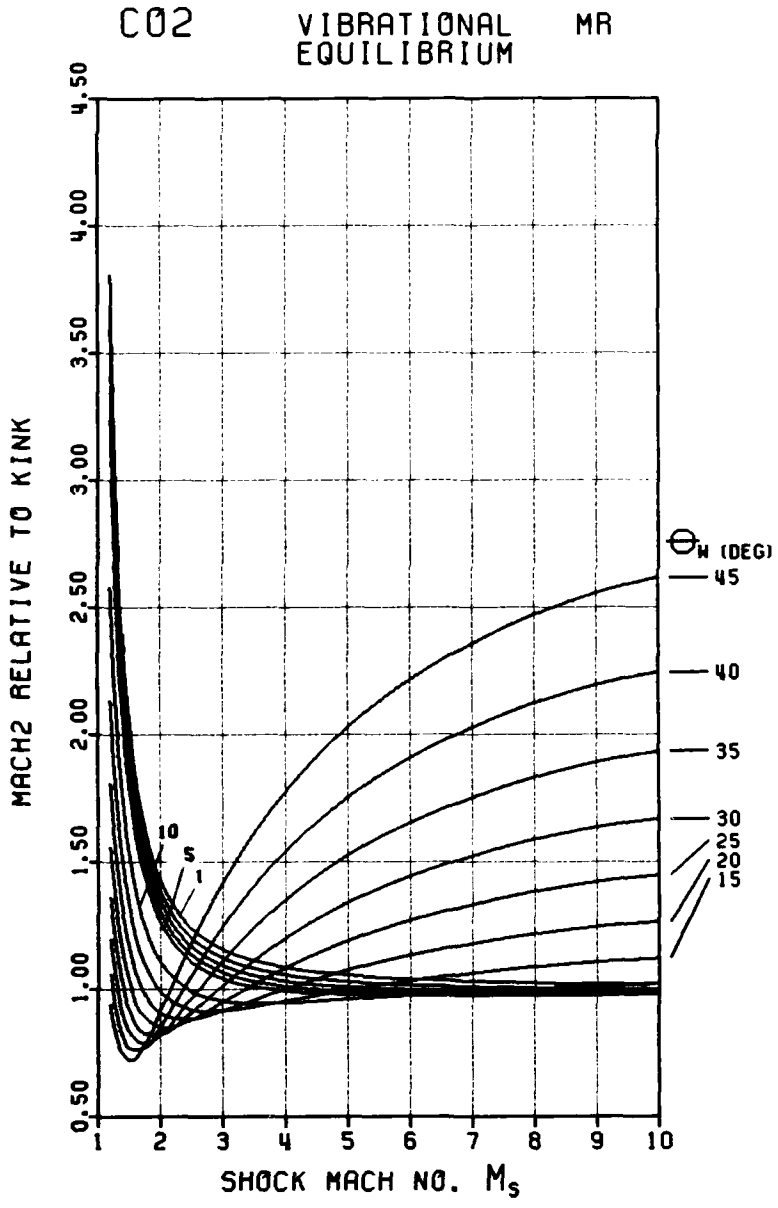

C02 VIBRATIONAL EQUILIBRIUM MR
RH03/RH00
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
1
2
3
4
5
6
7
8
9
10

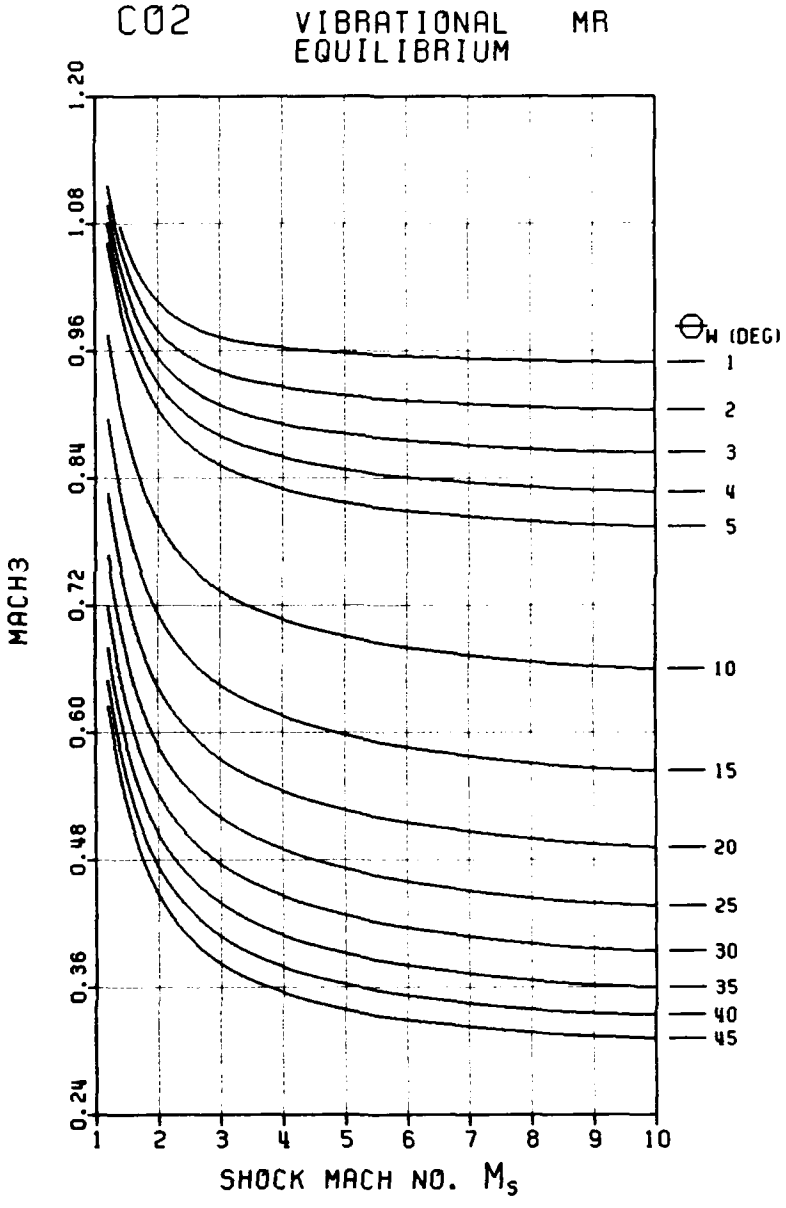

C02 VIBRATIONAL EQUILIBRIUM MR
P2/P0 AND P3/P0
SHOCK MACH NO. M_s
θ_w (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

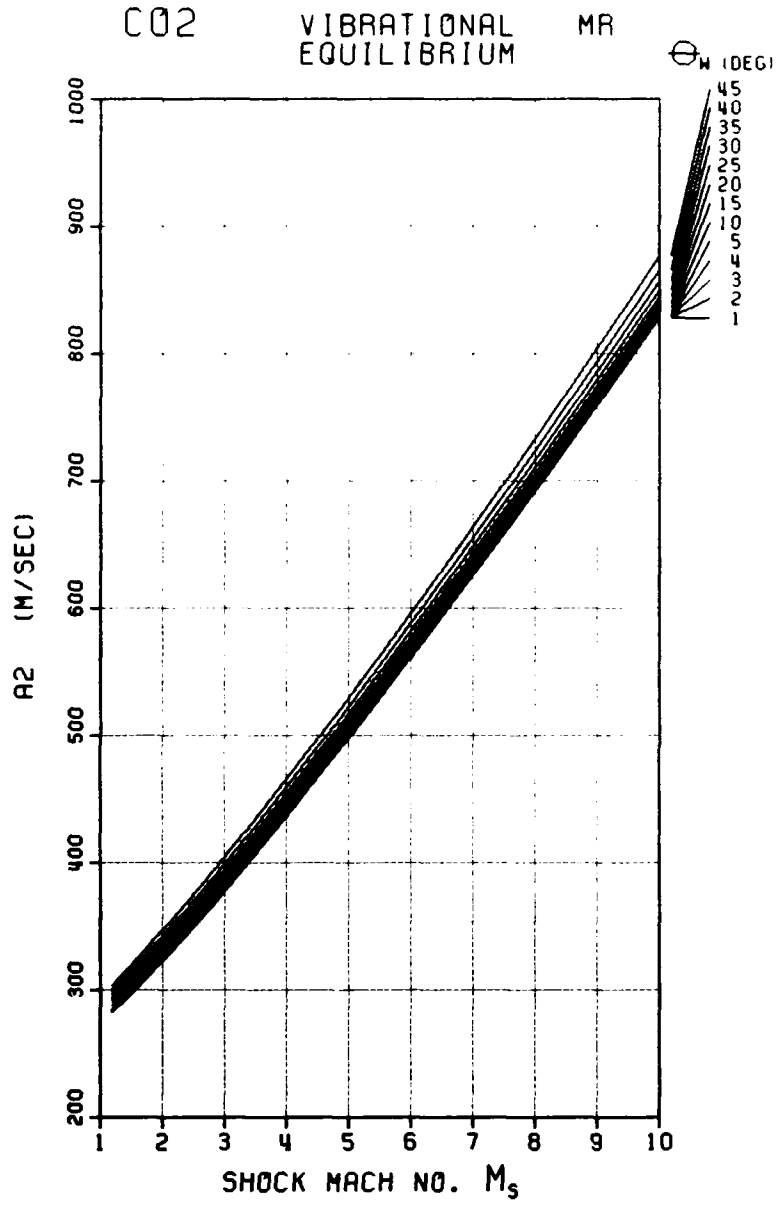

C02 VIBRATIONAL EQUILIBRIUM MR
MACH
SHOCK MACH NO. M_s
θ_w (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

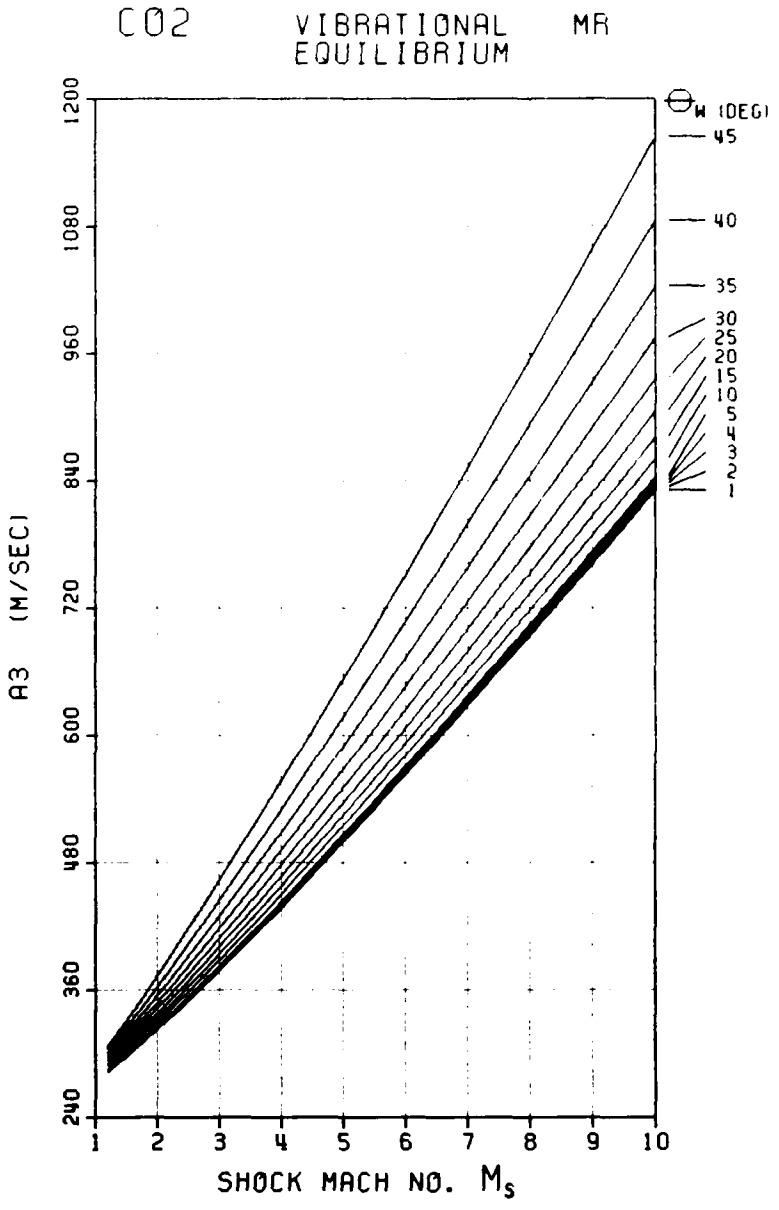

CO2 VIBRATIONAL EQUILIBRIUM MR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.60
1.00
1.40
1.80
2.20
2.60
3.00
3.40
3.80
1
2
3
4
5
6
7
8
9
10

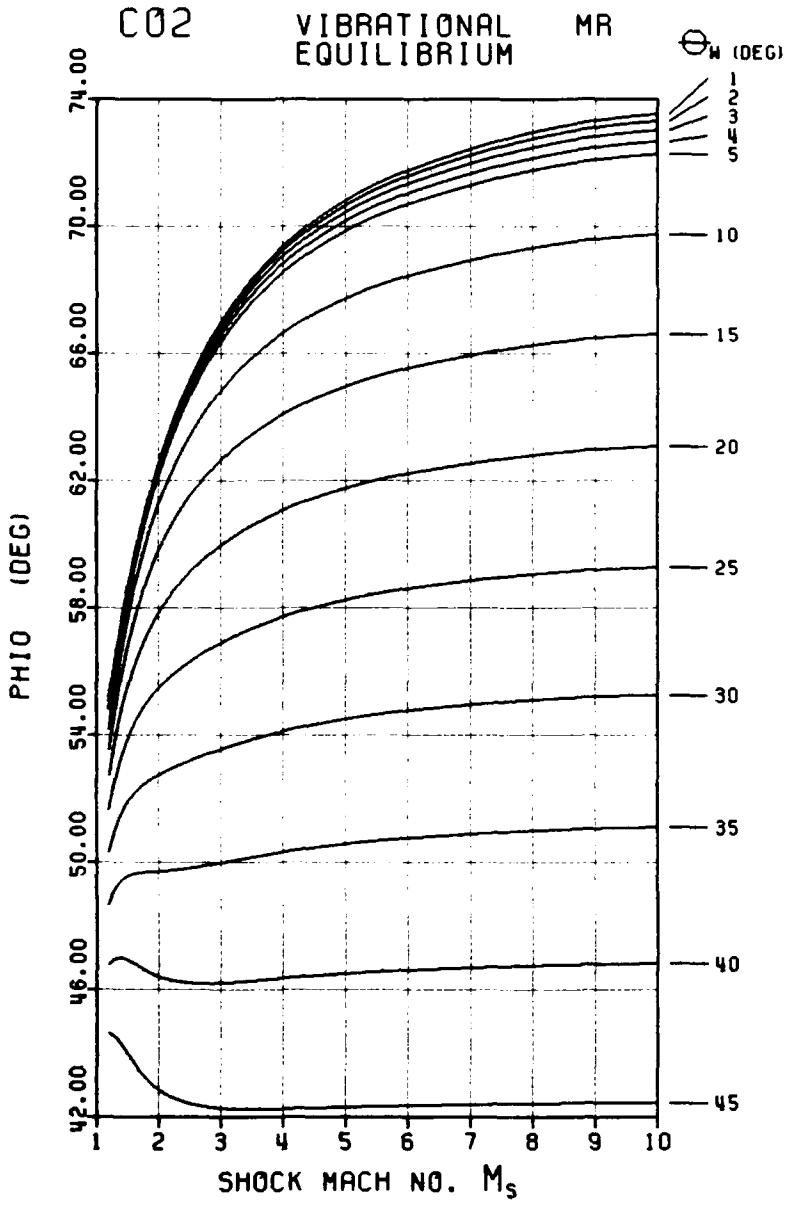

CO2 VIBRATIONAL EQUILIBRIUM MR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
1
2
3
4
5
6
7
8
9
10

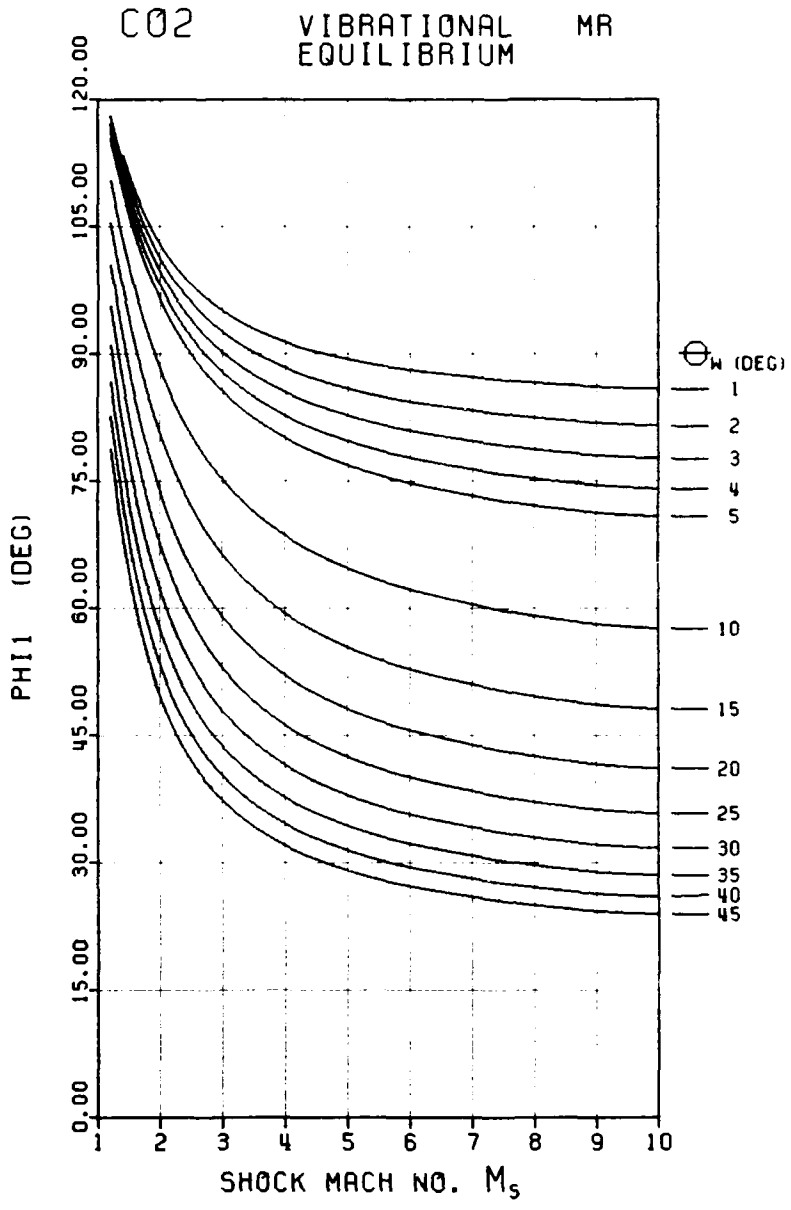

C02 VIBRATIONAL EQUILIBRIUM MR
MACH2 RELATIVE TO KINK
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
1

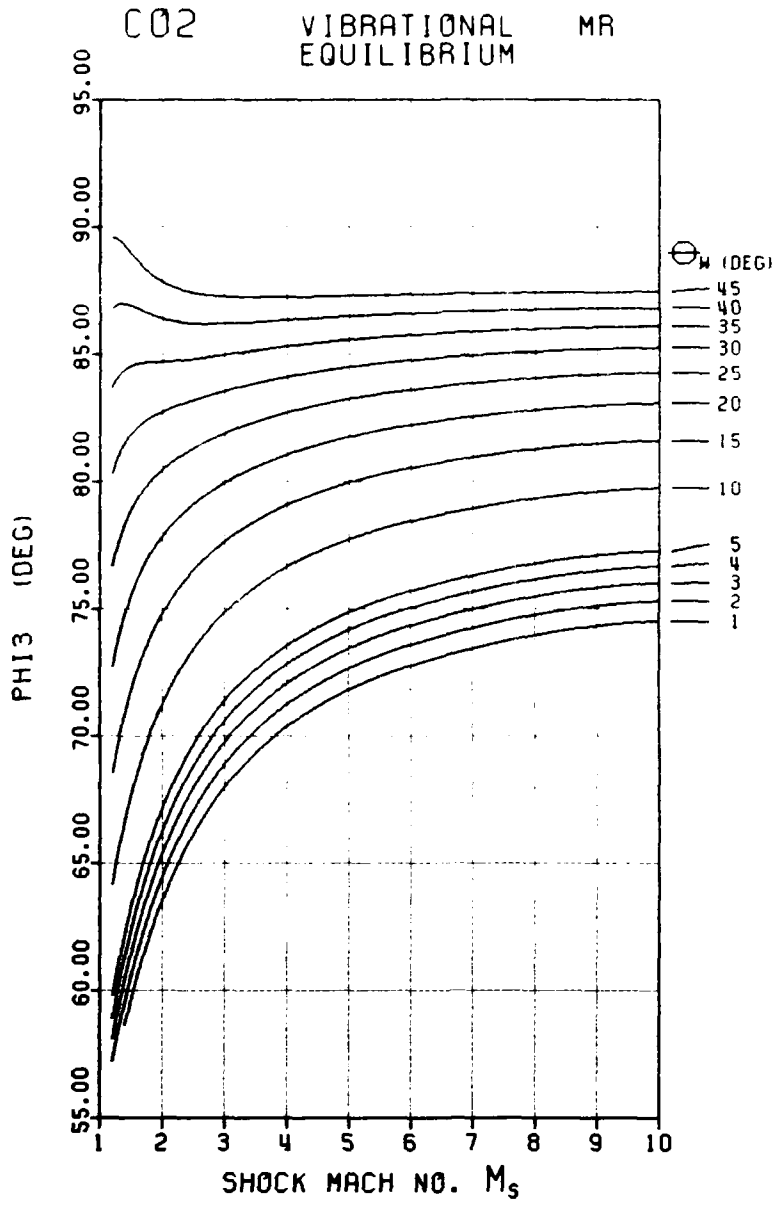

C02 VIBRATIONAL EQUILIBRIUM MR
MACH3
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

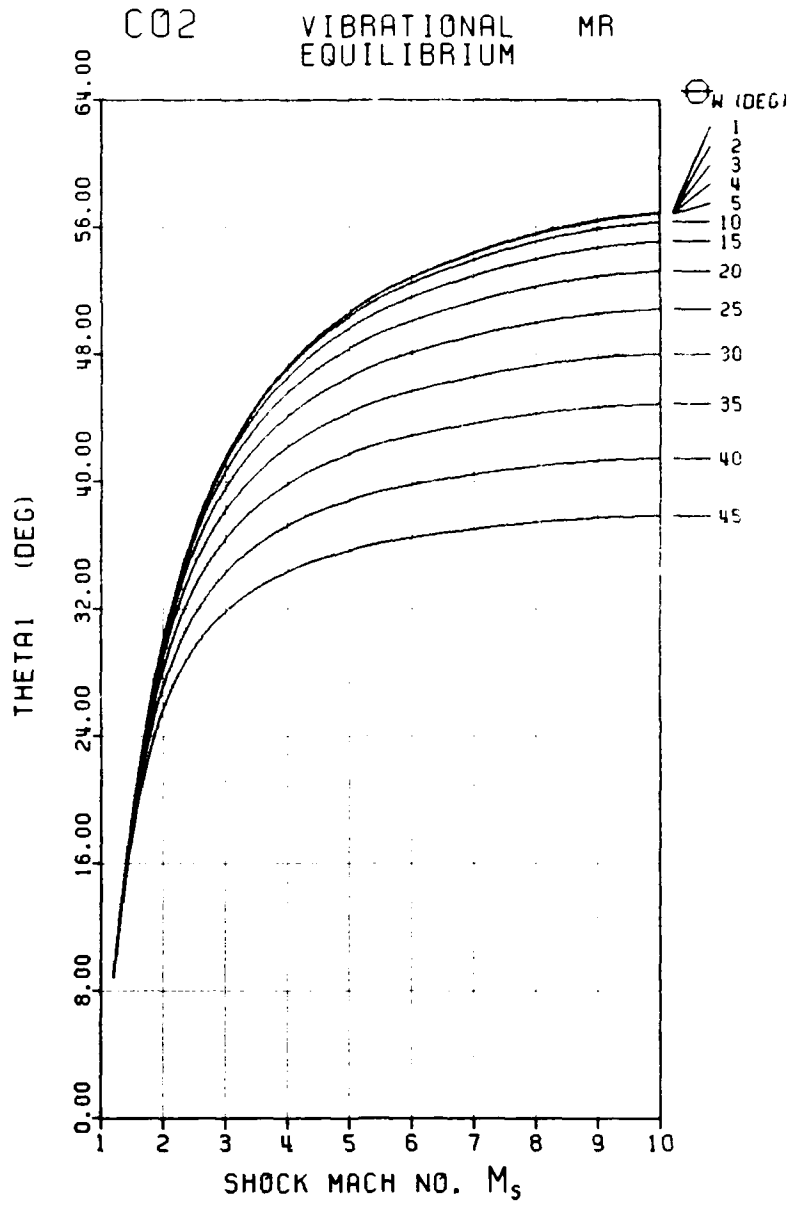

CO2 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A2 (M/SEC)
200
300
400
500
600
700
800
900
1000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

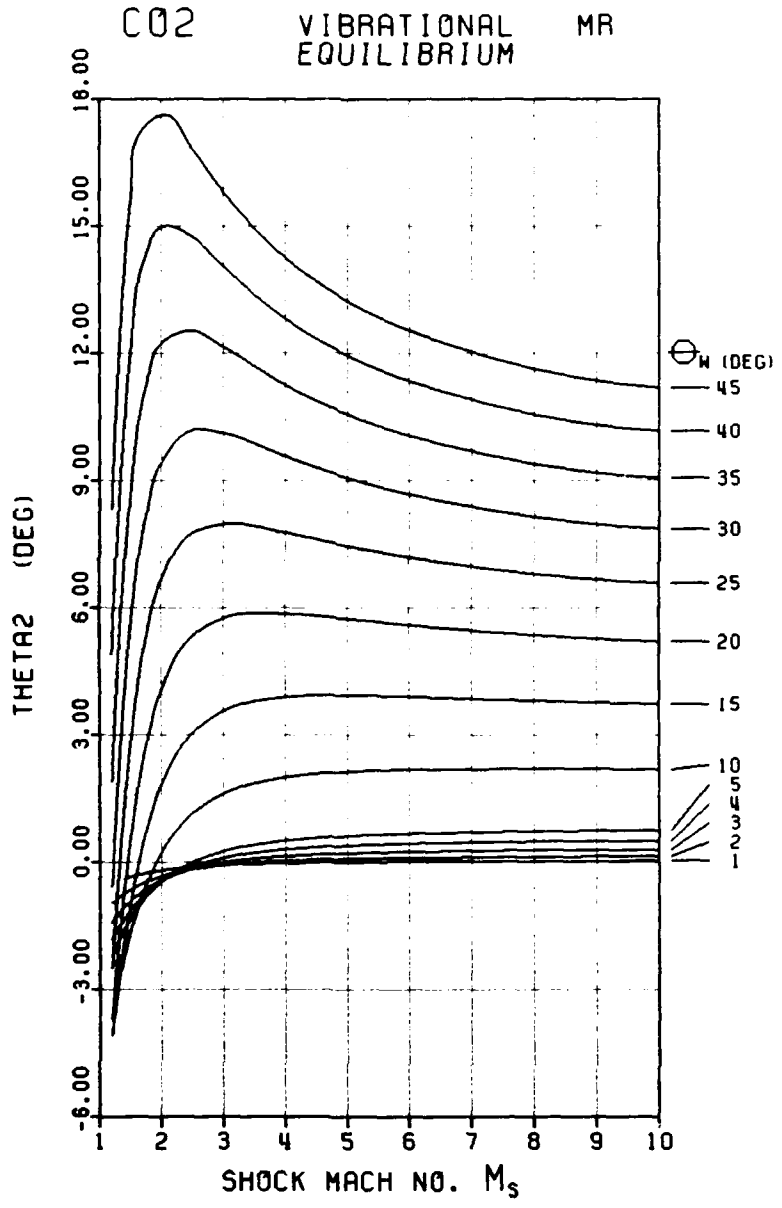

CO2 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A3 (M/SEC)
240
360
480
600
720
840
960
1080
1200
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

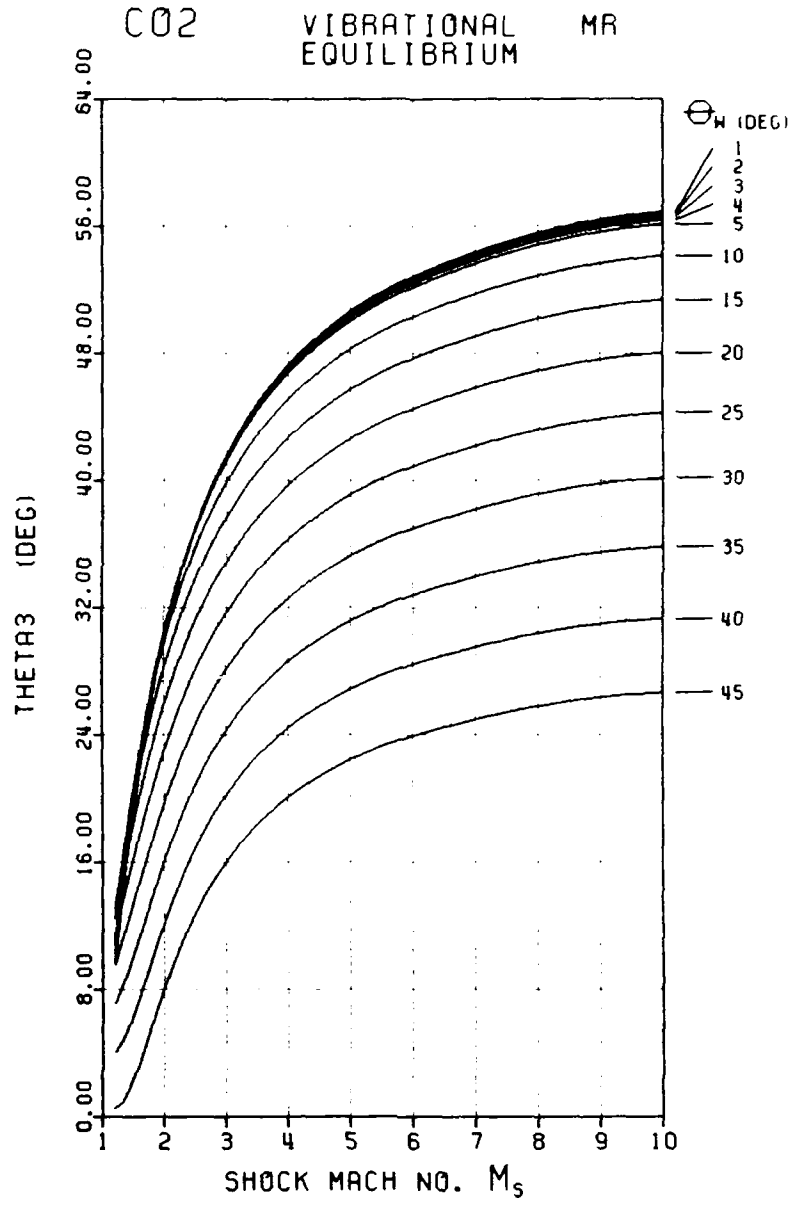

C02 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45
PHIO (DEG)
74.00
70.00
66.00
62.00
58.00
54.00
50.00
46.00
42.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

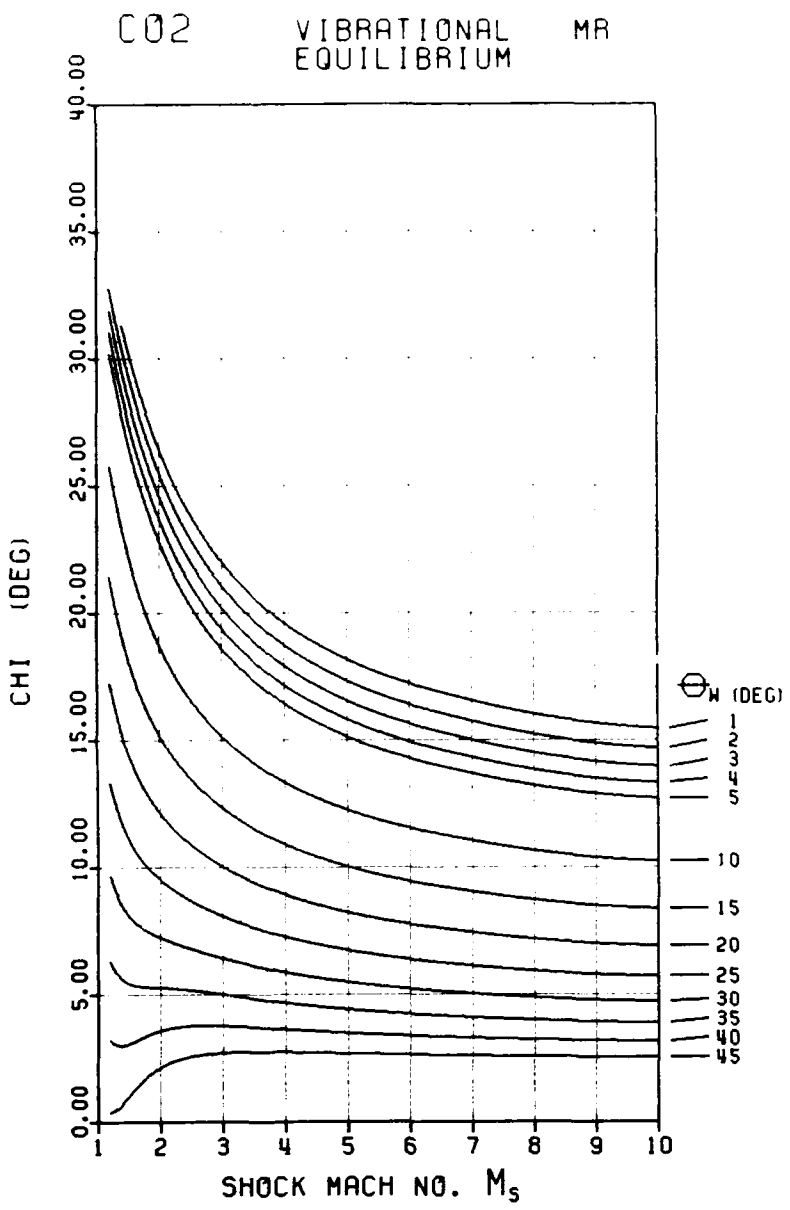

C02 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45
PHI1 (DEG)
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

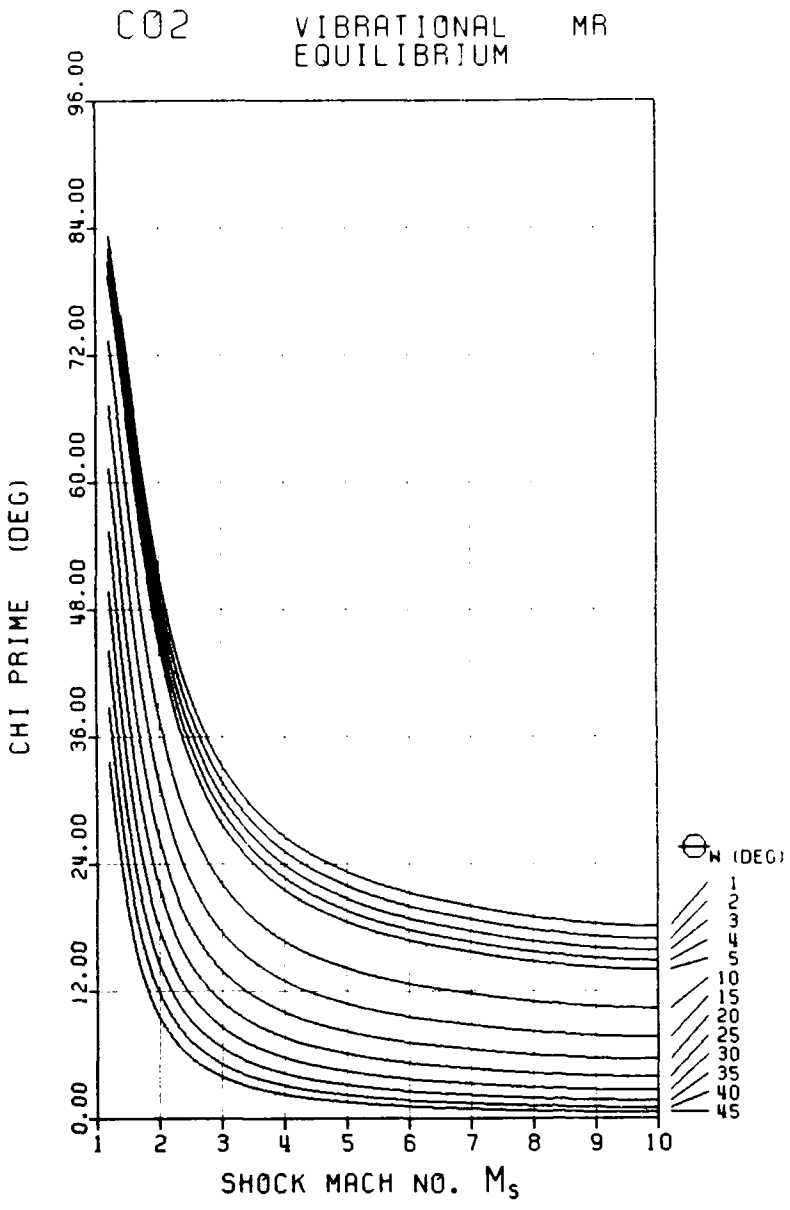

CO2 VIBRATIONAL EQUILIBRIUM MR
PHI3 (DEG)
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

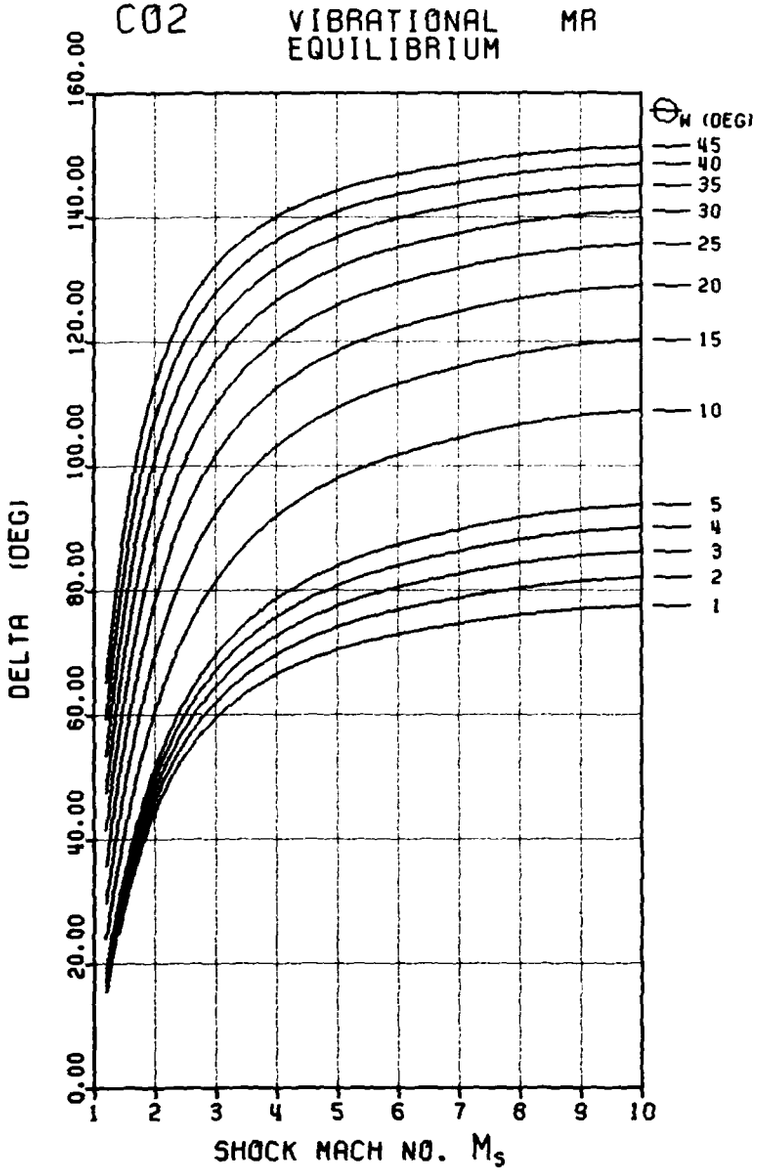

CO2 VIBRATIONAL EQUILIBRIUM MR
THETA1 (DEG)
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

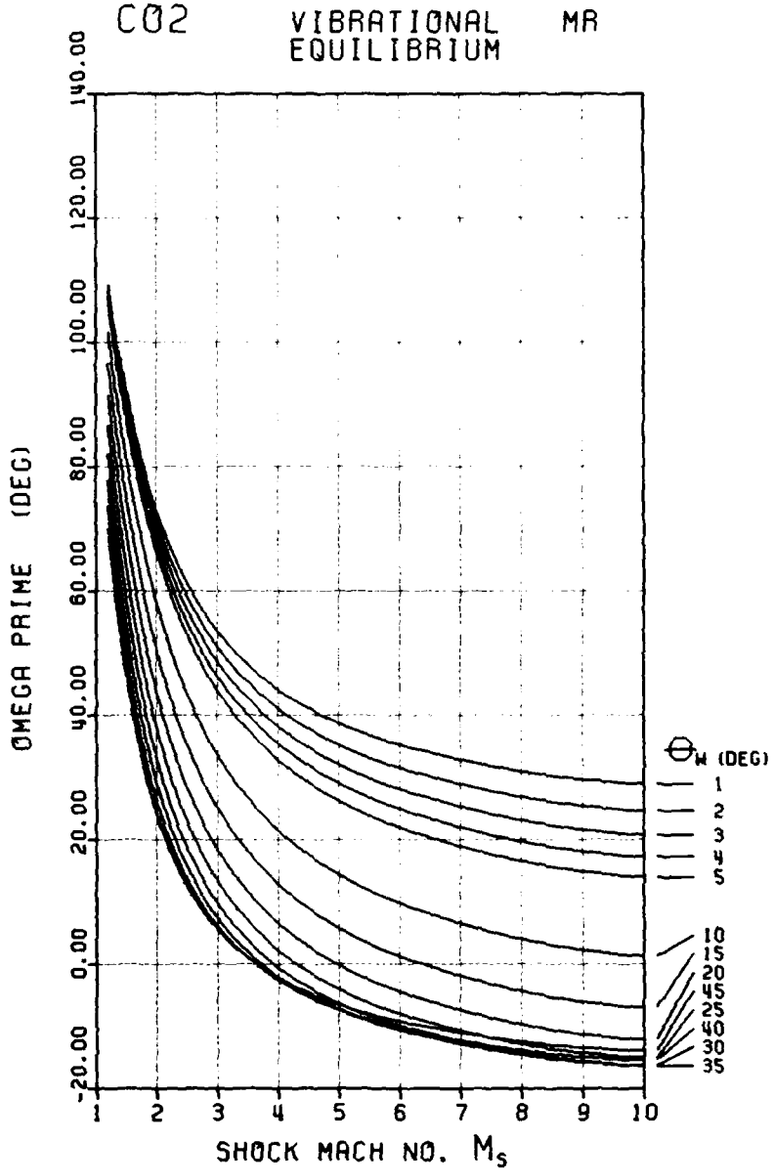

CO2 VIBRATIONAL EQUILIBRIUM MR
THETA2 (DEG)
16.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

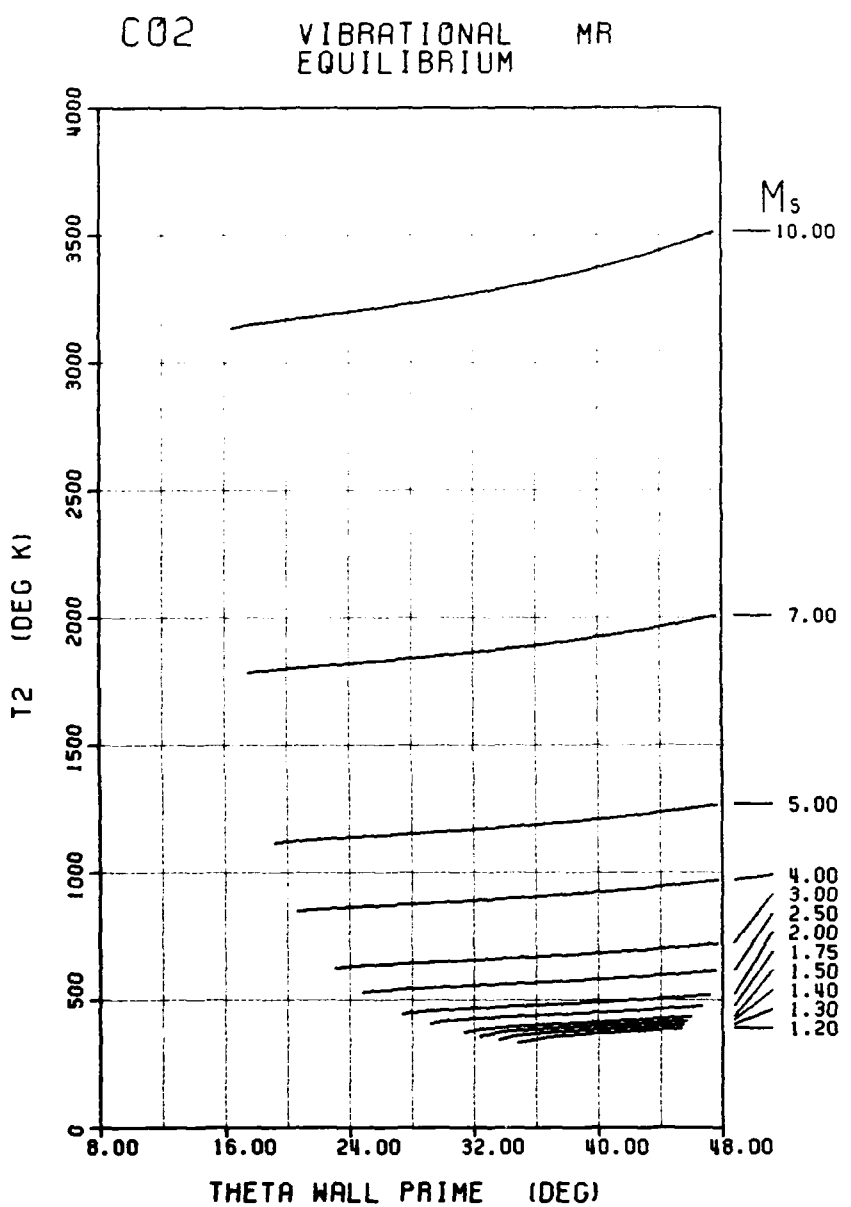

CO2 VIBRATIONAL EQUILIBRIUM MR
THETA3 (DEG)
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

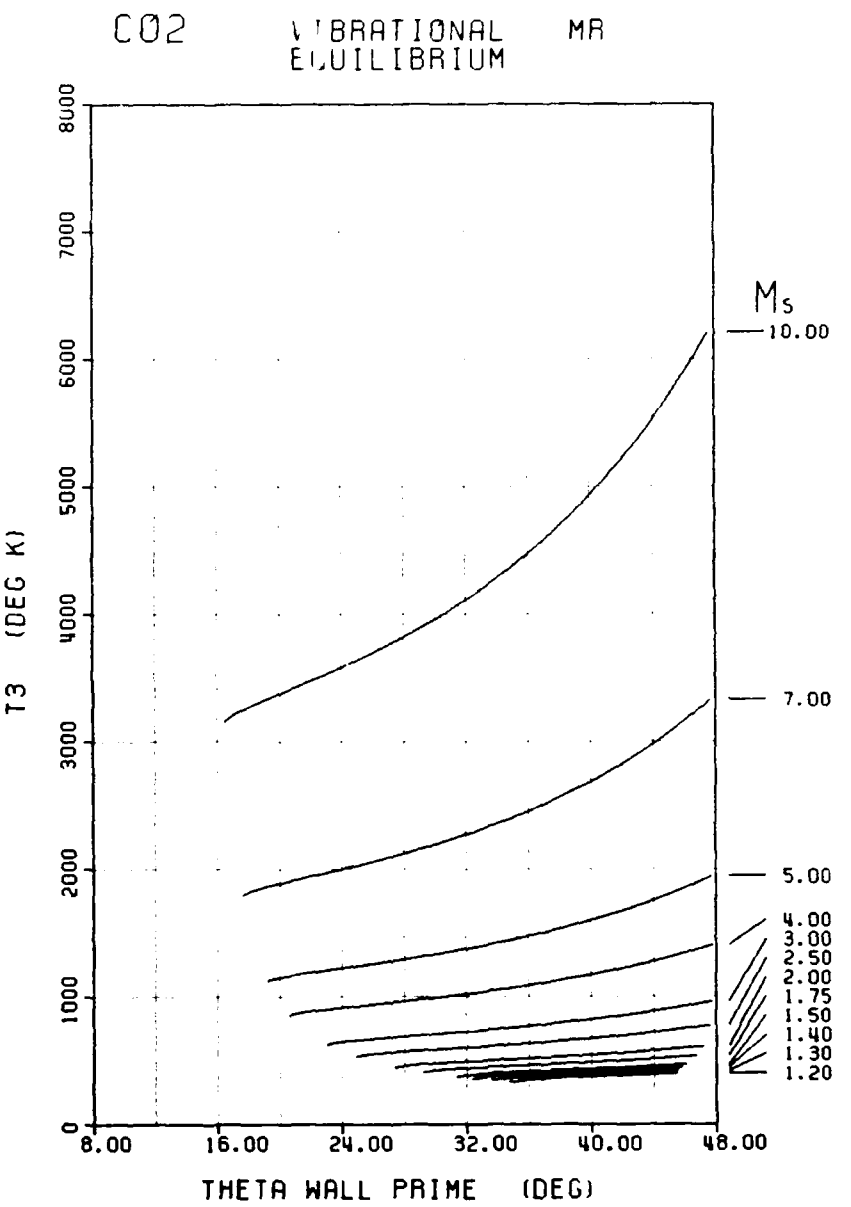

CO2 VIBRATIONAL EQUILIBRIUM MR
CHI (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

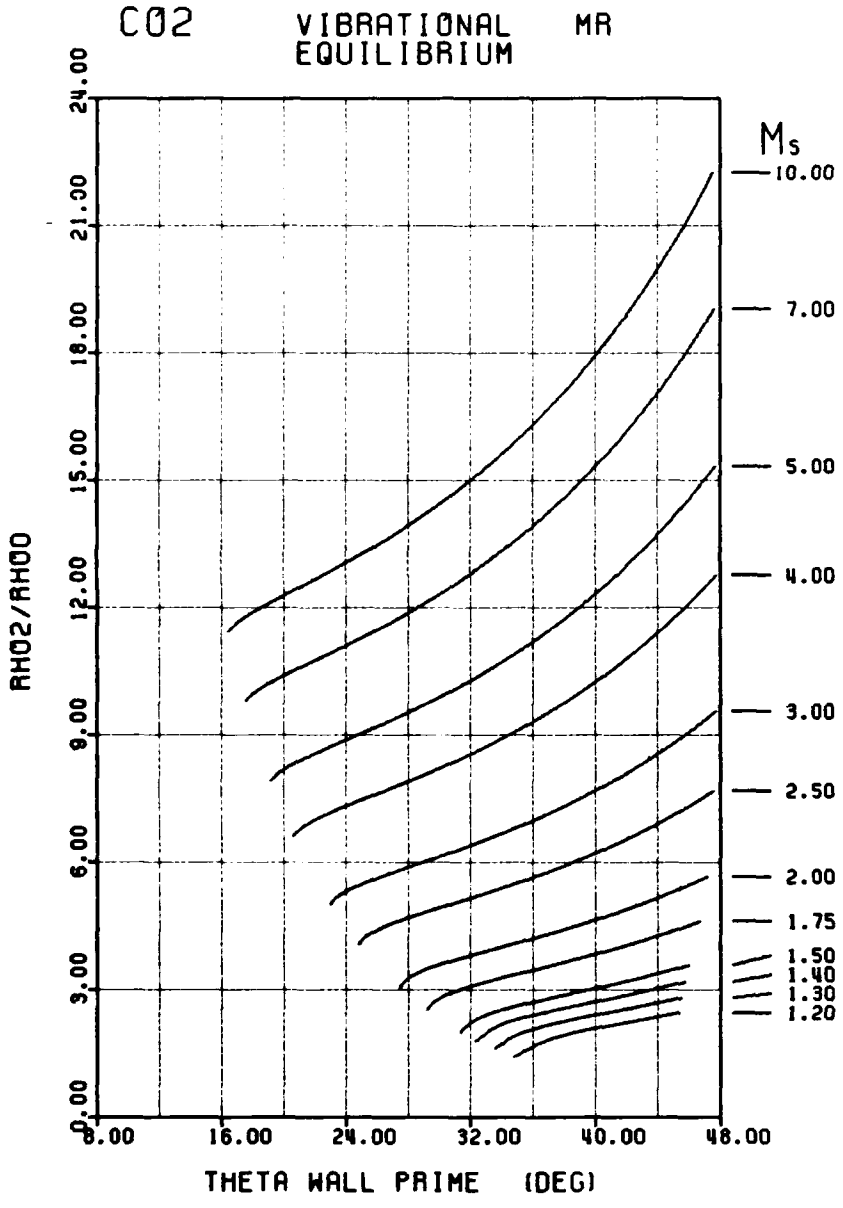

CO2 VIBRATIONAL EQUILIBRIUM MR
CHI PRIME (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

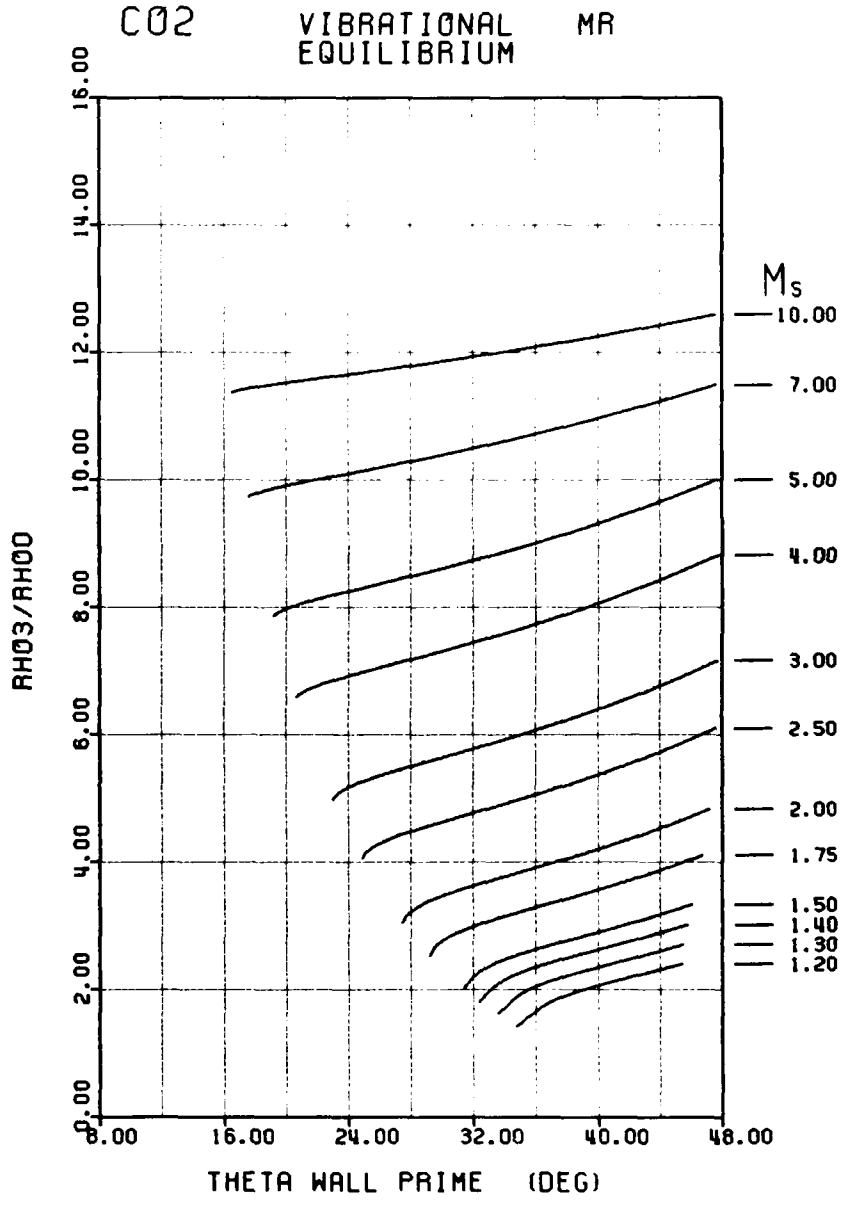

C02 VIBRATIONAL EQUILIBRIUM MR
DELTA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

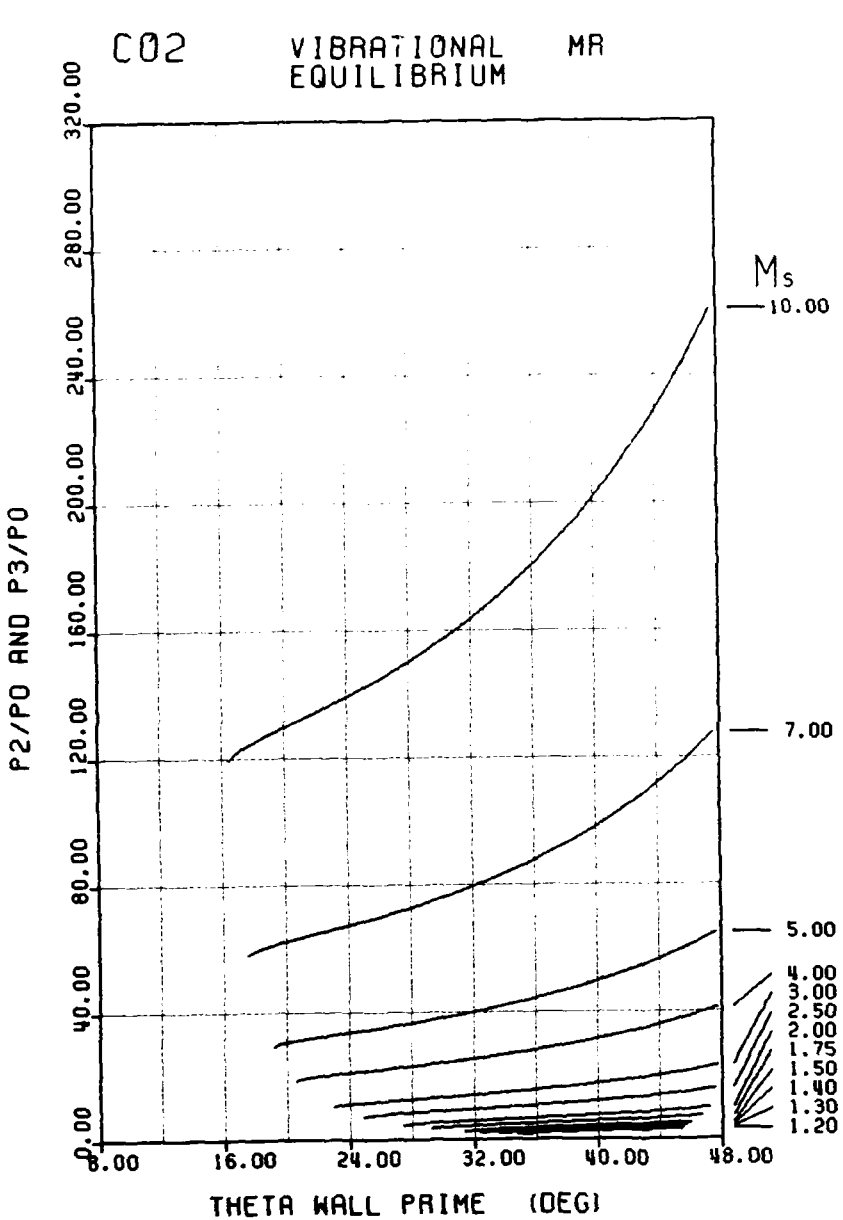

C02 VIBRATIONAL EQUILIBRIUM MR
OMEGA PRIME (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40

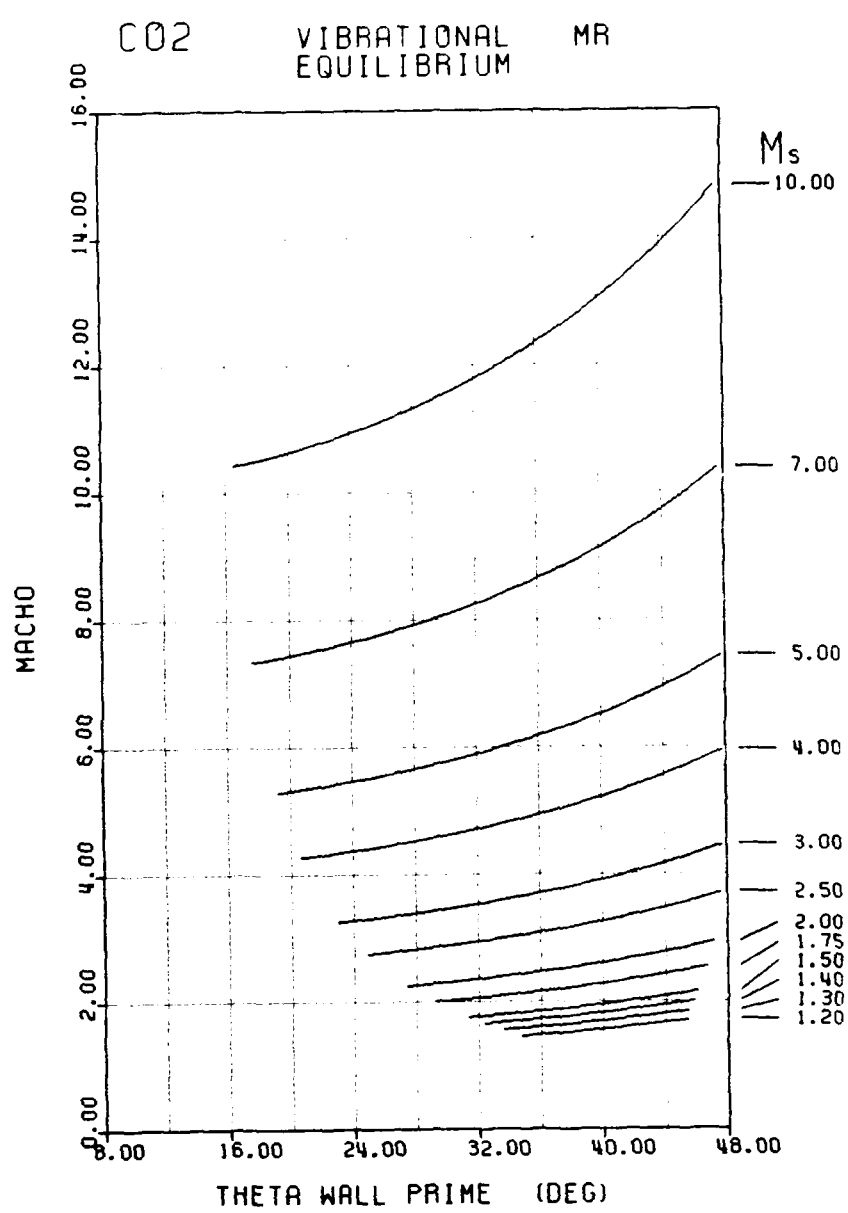

C02 VIBRATIONAL EQUILIBRIUM MR
T2 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
500
1000
1500
2000
2500
3000
3500
4000
8.00
16.00
24.00
32.00
40.00
48.00

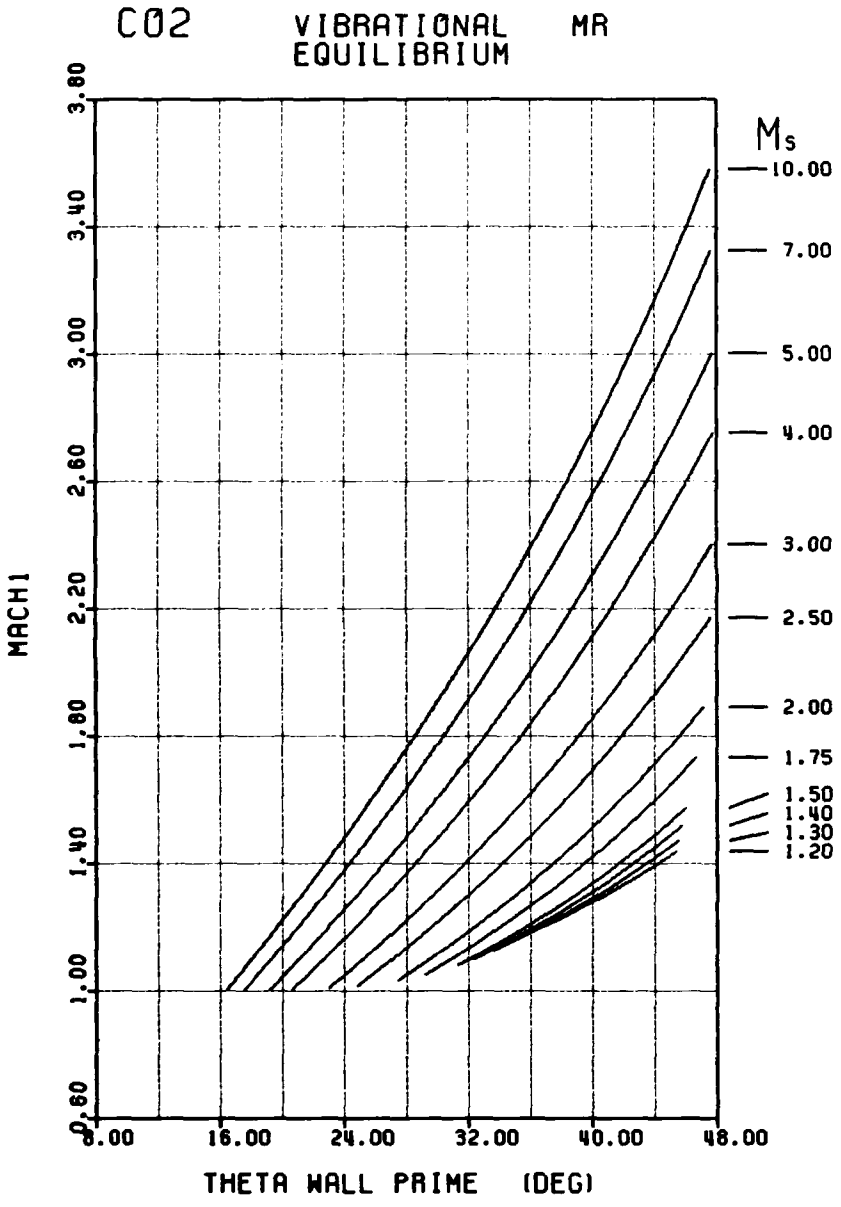

C02 VIBRATIONAL EQUILIBRIUM MR
T3 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
1000
2000
3000
4000
5000
6000
7000
8000
8.00
16.00
24.00
32.00
40.00
48.00

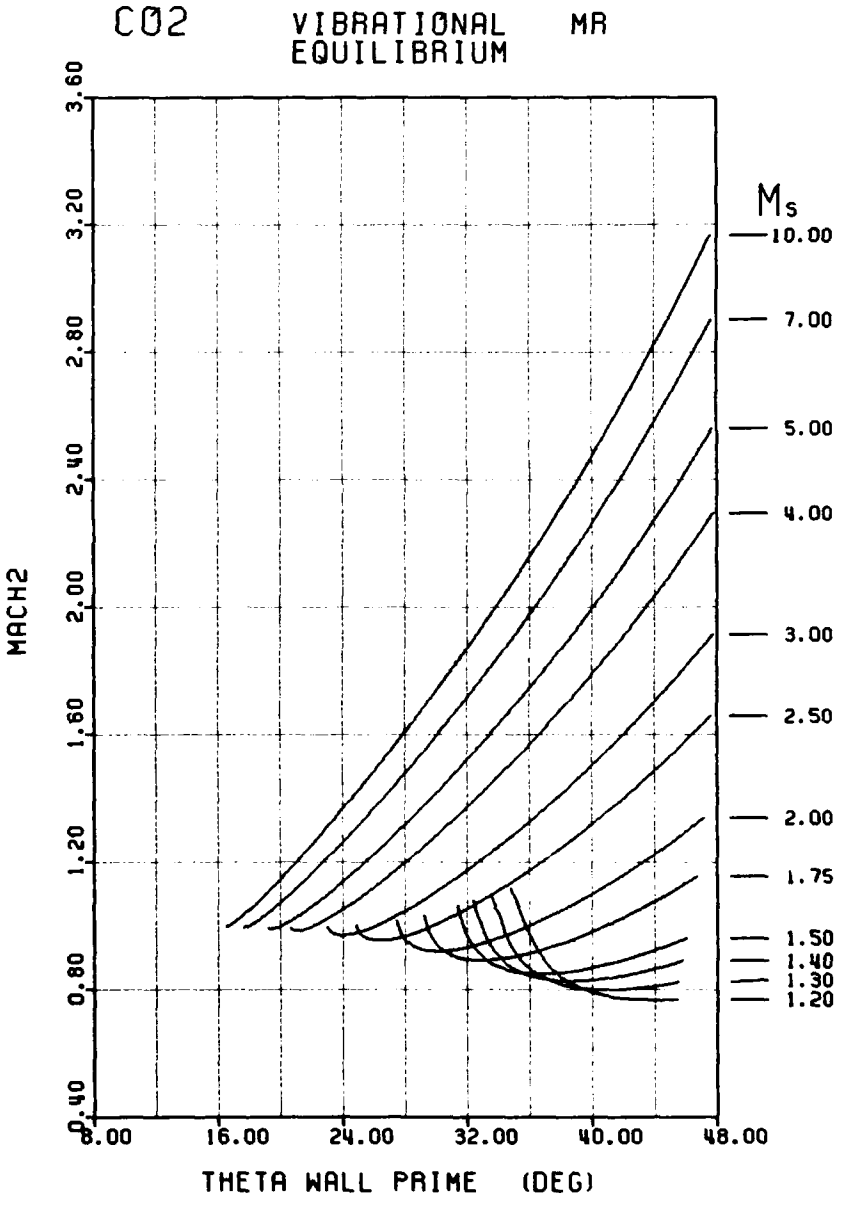

C02 VIBRATIONAL EQUILIBRIUM MR
RH02/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
8.00
16.00
24.00
32.00
40.00
48.00

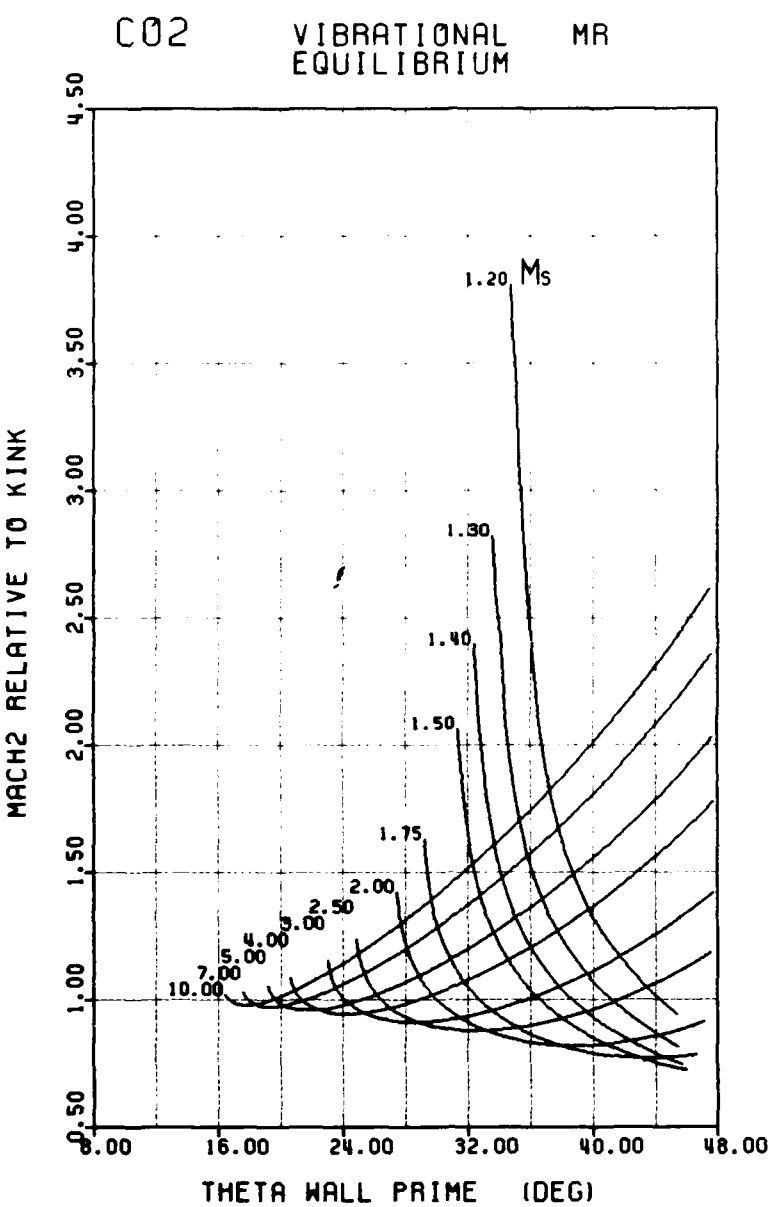

C02 VIBRATIONAL EQUILIBRIUM MR
RH03/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
8.00
16.00
24.00
32.00
40.00
48.00

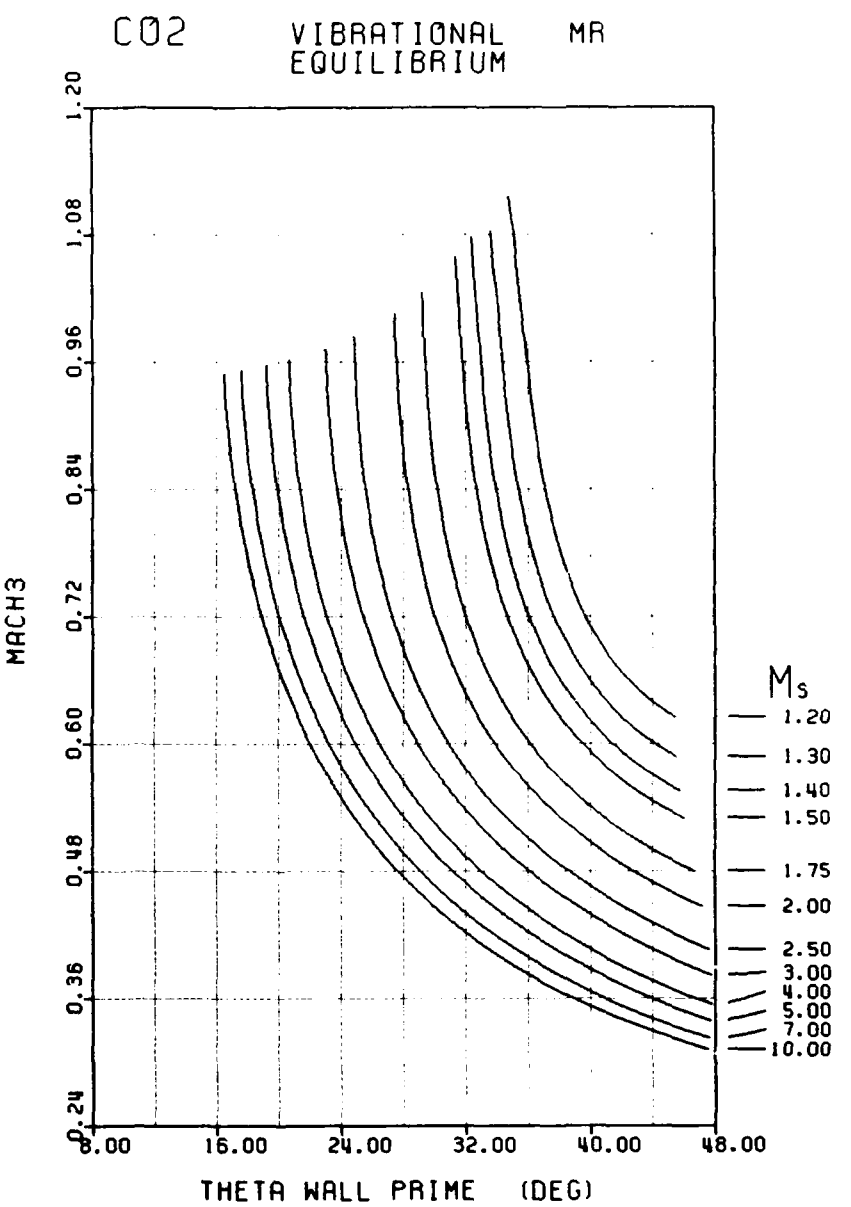

CO2 VIBRATIONAL EQUILIBRIUM MR
P2/PO AND P3/PO
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
8.00
16.00
24.00
32.00
40.00
48.00

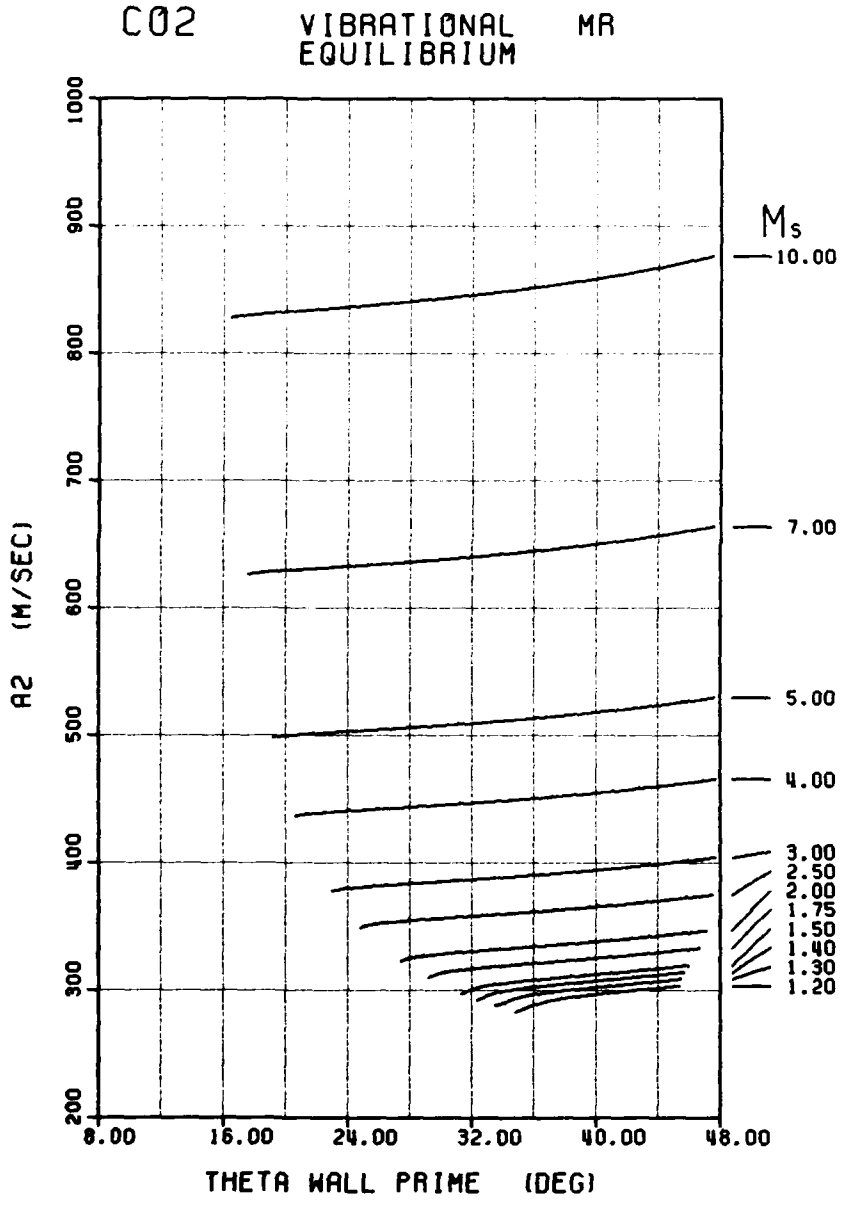

CO2 VIBRATIONAL EQUILIBRIUM MR
MACHO
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
8.00
16.00
24.00
32.00
40.00
48.00

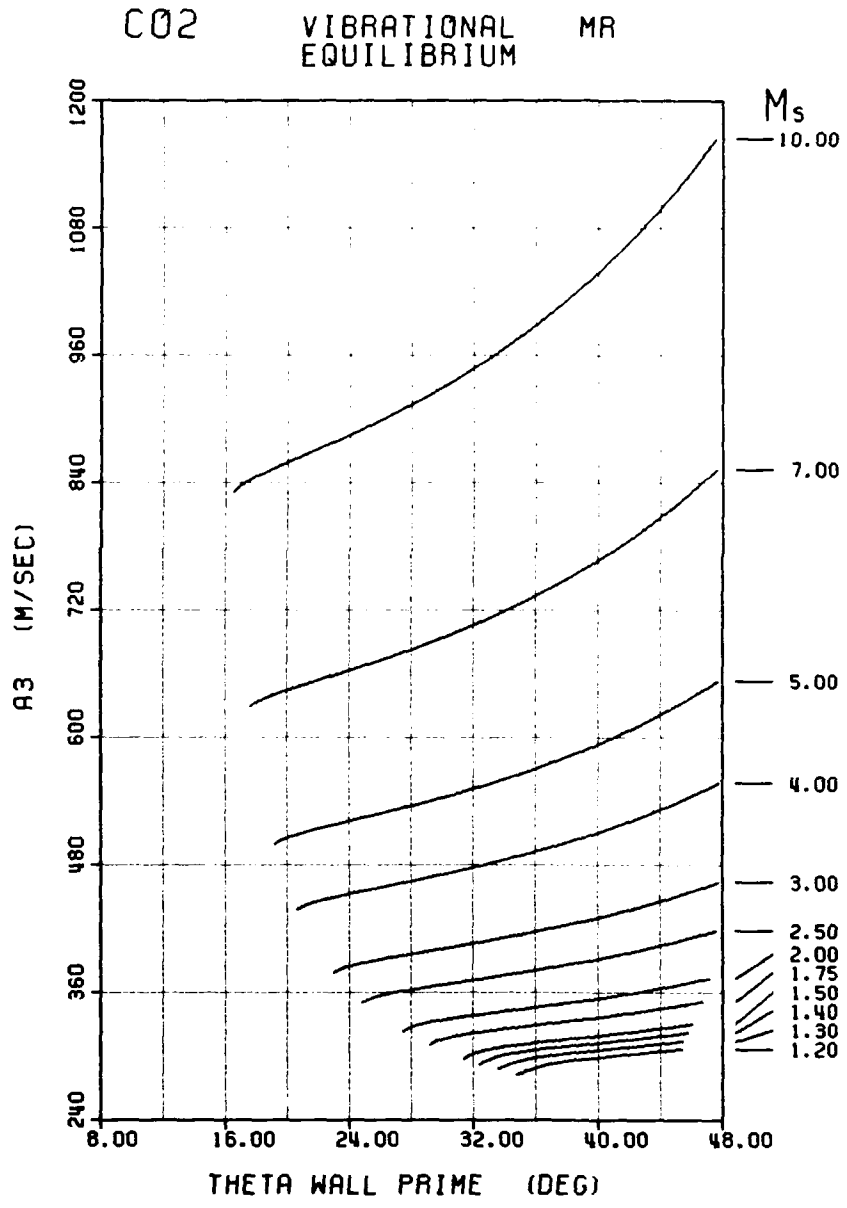

C02 VIBRATIONAL EQUILIBRIUM MR
MACH1
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.60
1.00
1.40
1.80
2.20
2.60
3.00
3.40
3.80
8.00
16.00
24.00
32.00
40.00
48.00

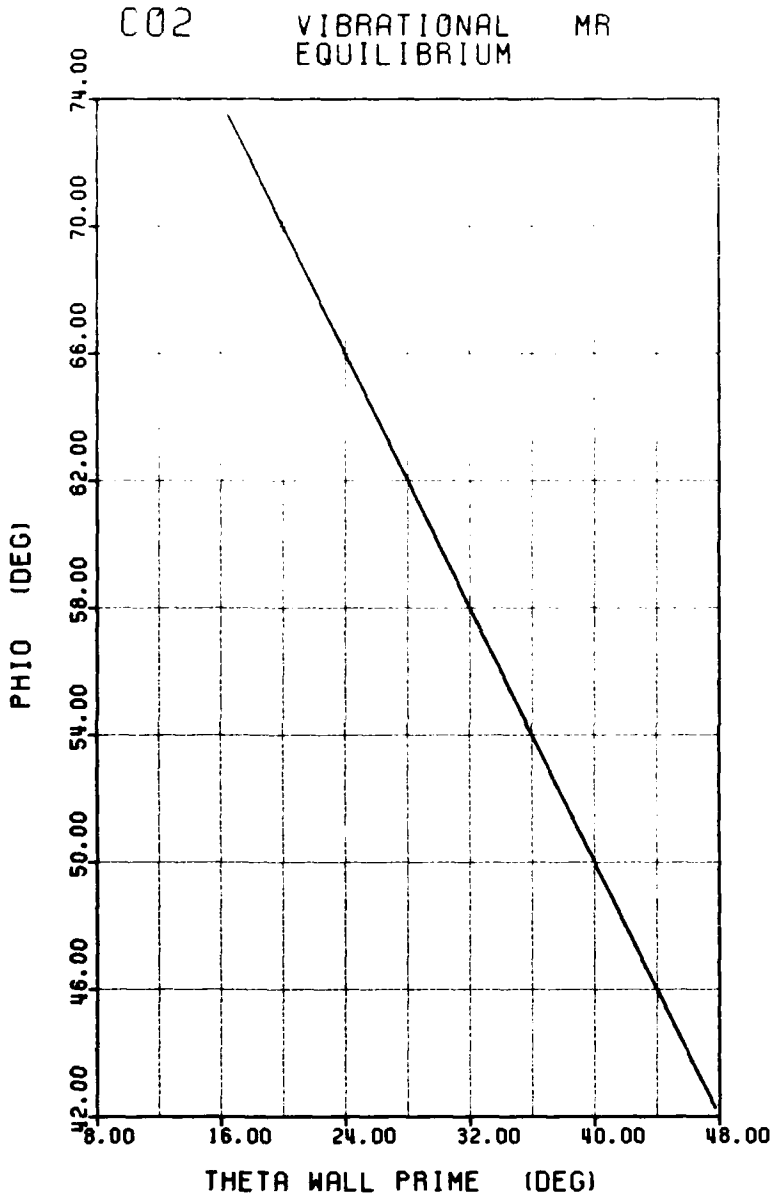

C02 VIBRATIONAL EQUILIBRIUM MR
MACH2
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
8.00
16.00
24.00
32.00
40.00
48.00

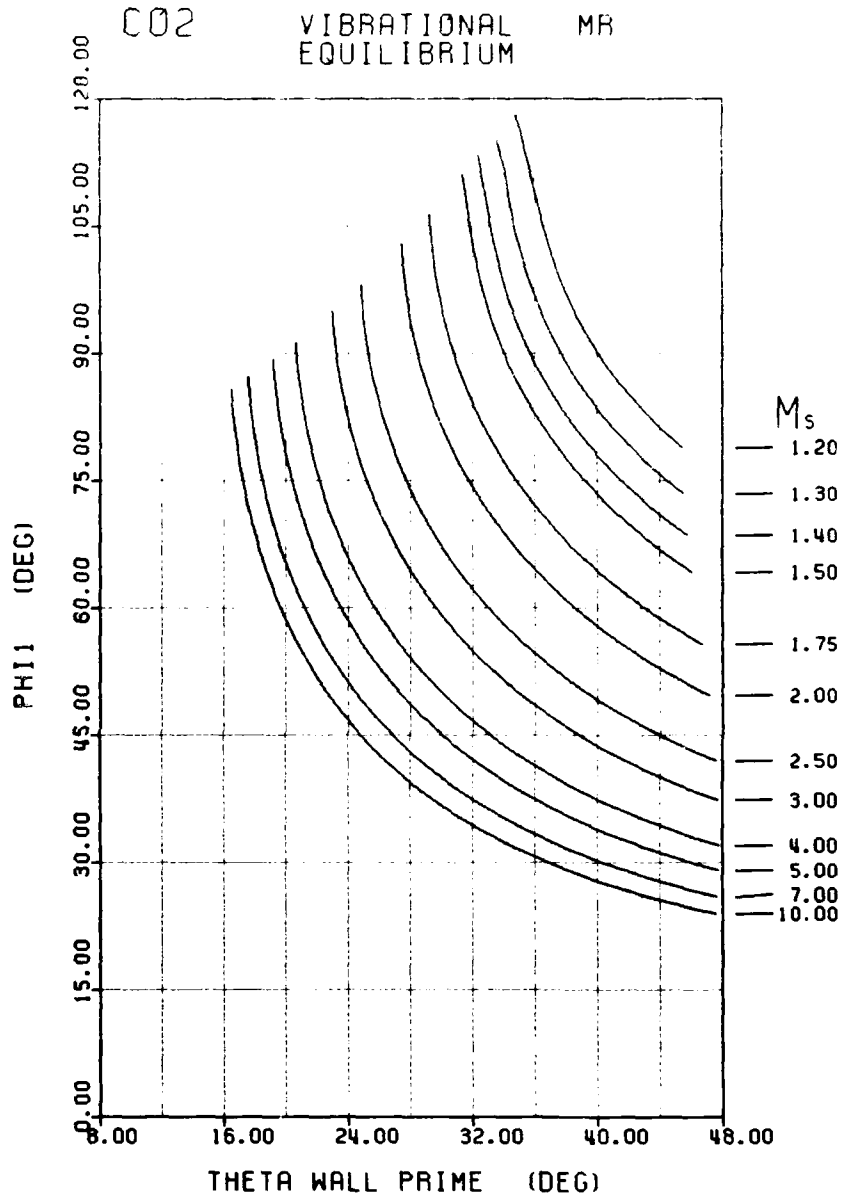

C02 VIBRATIONAL EQUILIBRIUM MR
MACH2 RELATIVE TO KINK
THETA WALL PRIME (DEG)
1.20 Ms
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
8.00
16.00
24.00
32.00
40.00
48.00

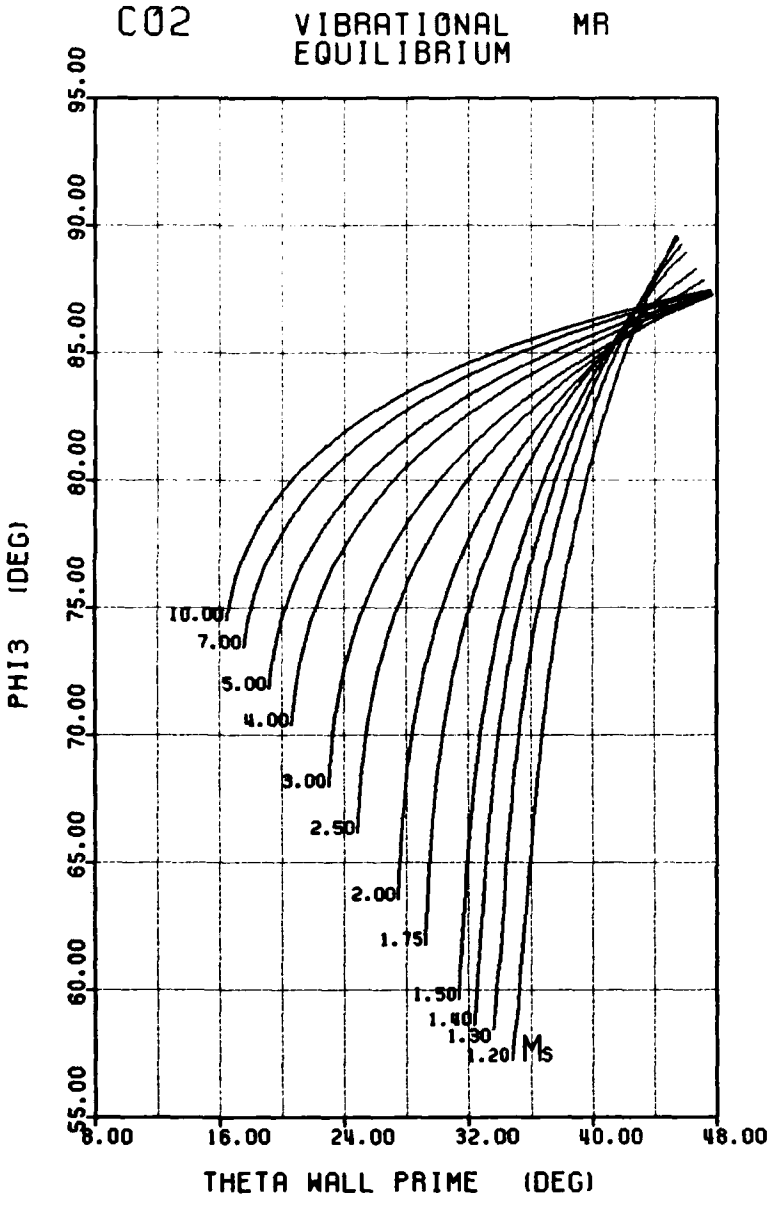

C02 VIBRATIONAL EQUILIBRIUM MR
MACH3
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.24
0.36
0.48
0.60
0.72
0.84
0.96
1.08
1.20
8.00
16.00
24.00
32.00
40.00
48.00

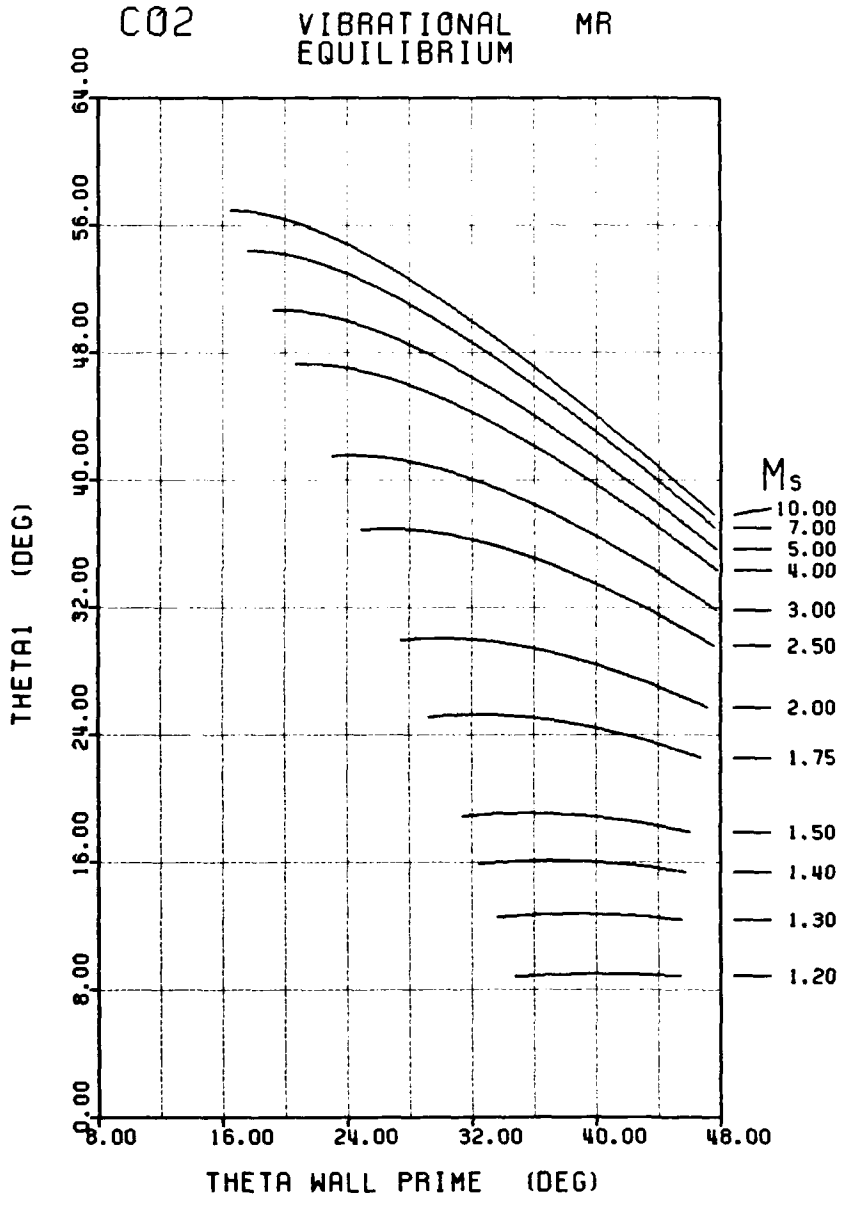

C02 VIBRATIONAL EQUILIBRIUM MR
A2 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
200
300
400
500
600
700
800
900
1000
8.00
16.00
24.00
32.00
40.00
48.00

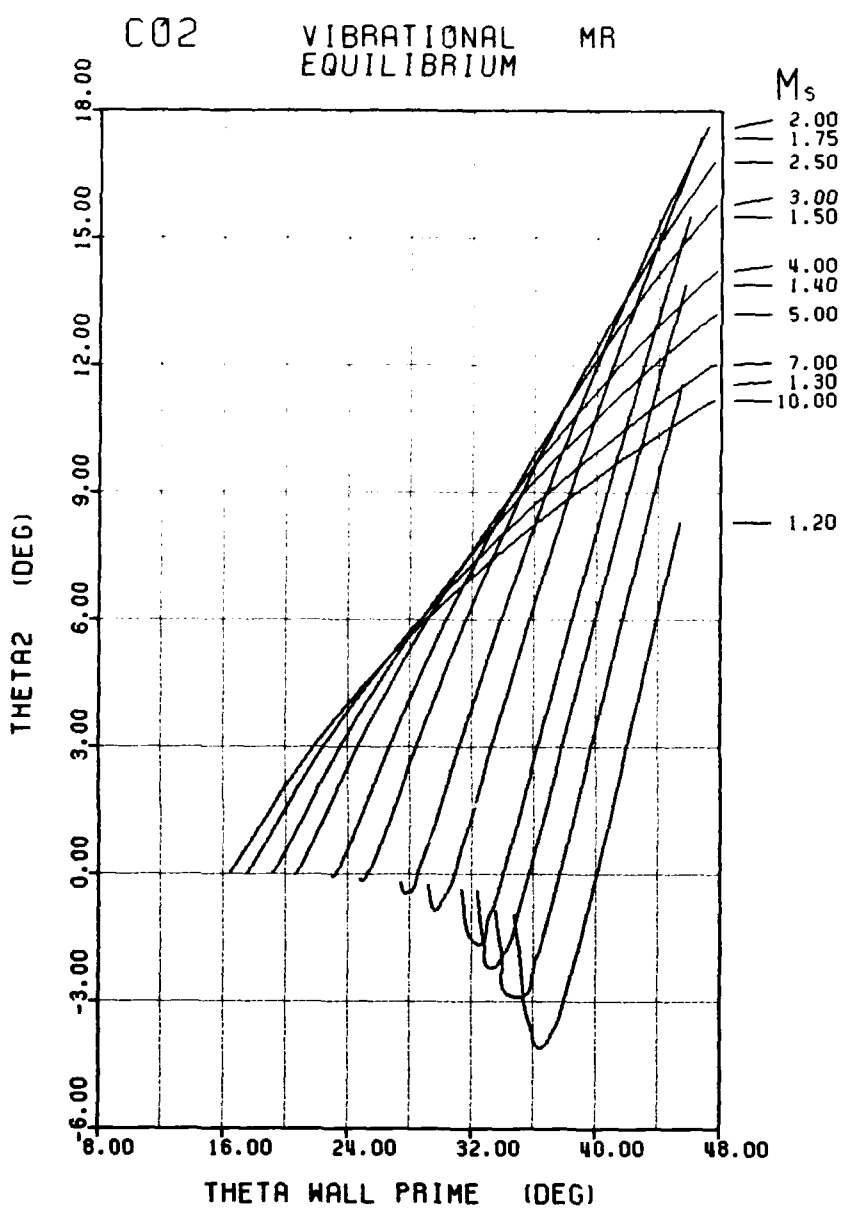

C02 VIBRATIONAL EQUILIBRIUM MR
A3 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
240
360
480
600
720
840
960
1080
1200
8.00
16.00
24.00
32.00
40.00
48.00

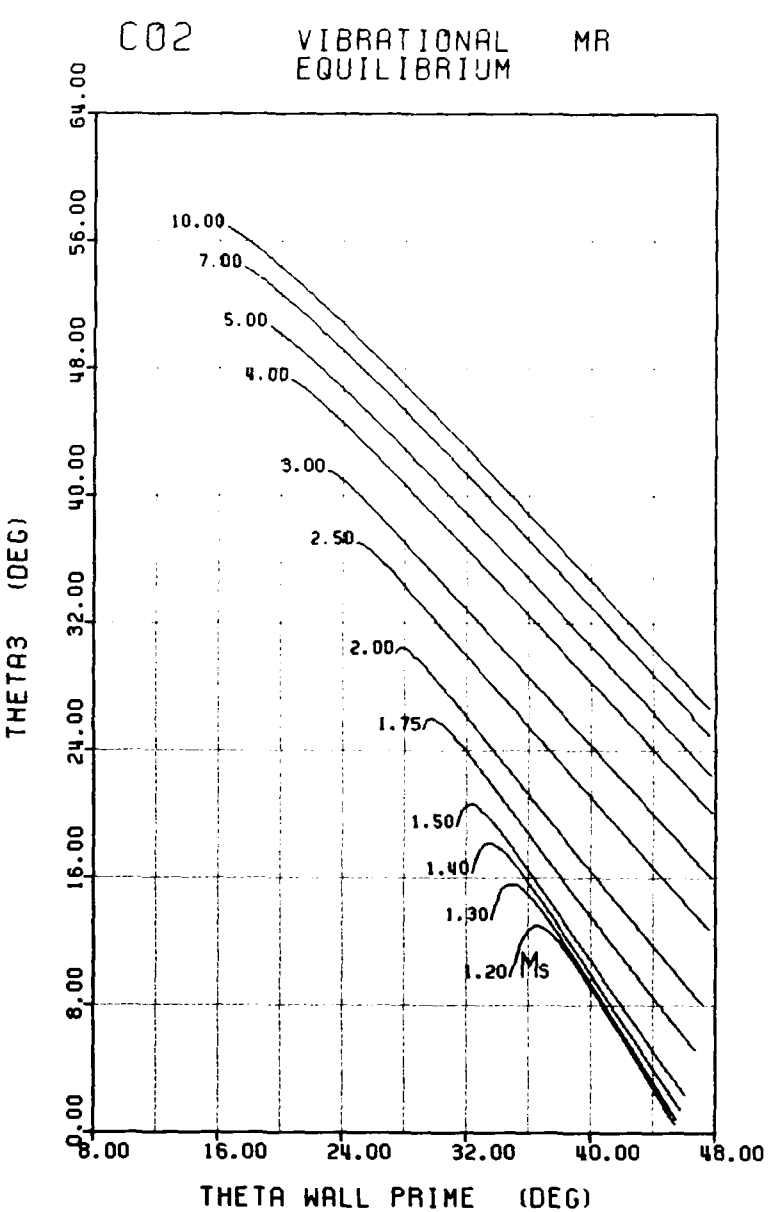

CO2 VIBRATIONAL EQUILIBRIUM MR
PHI0 (DEG)
74.00
70.00
66.00
62.00
58.00
54.00
50.00
46.00
42.00
8.00
16.00
24.00
32.00
40.00
48.00
THETA WALL PRIME (DEG)

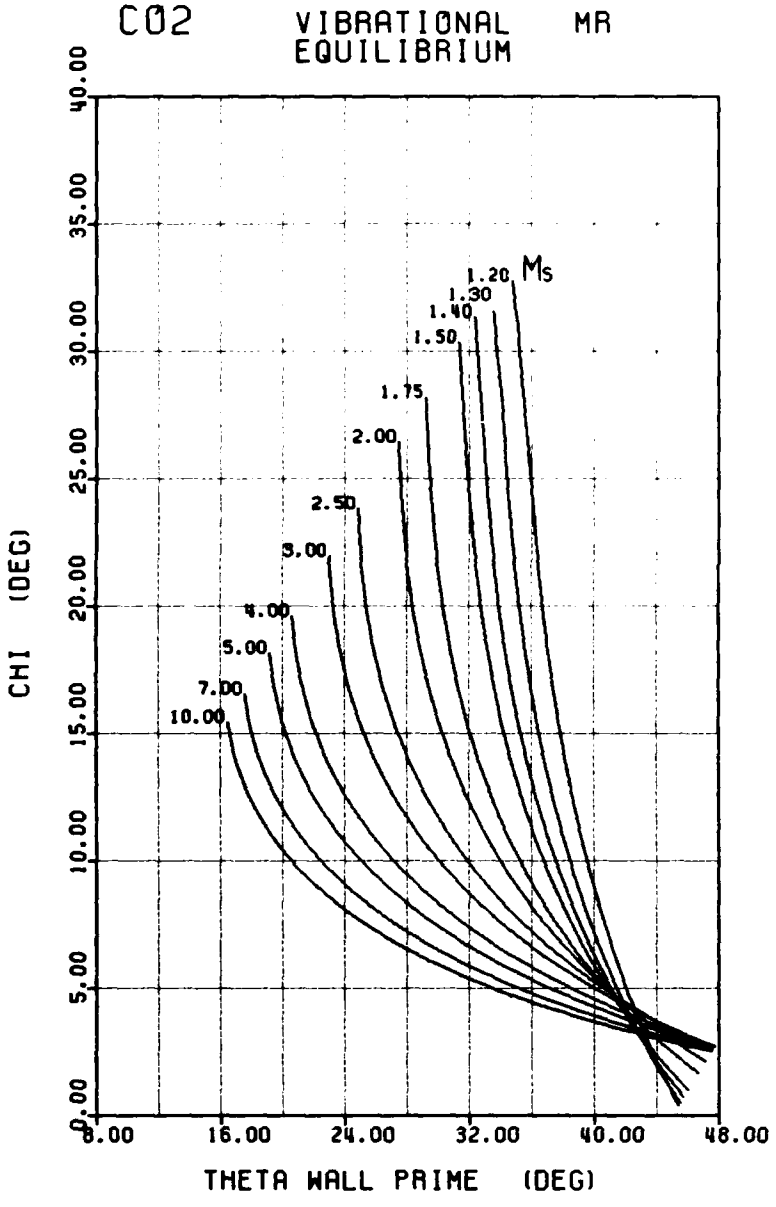

CO2 VIBRATIONAL EQUILIBRIUM MR
PHI1 (DEG)
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

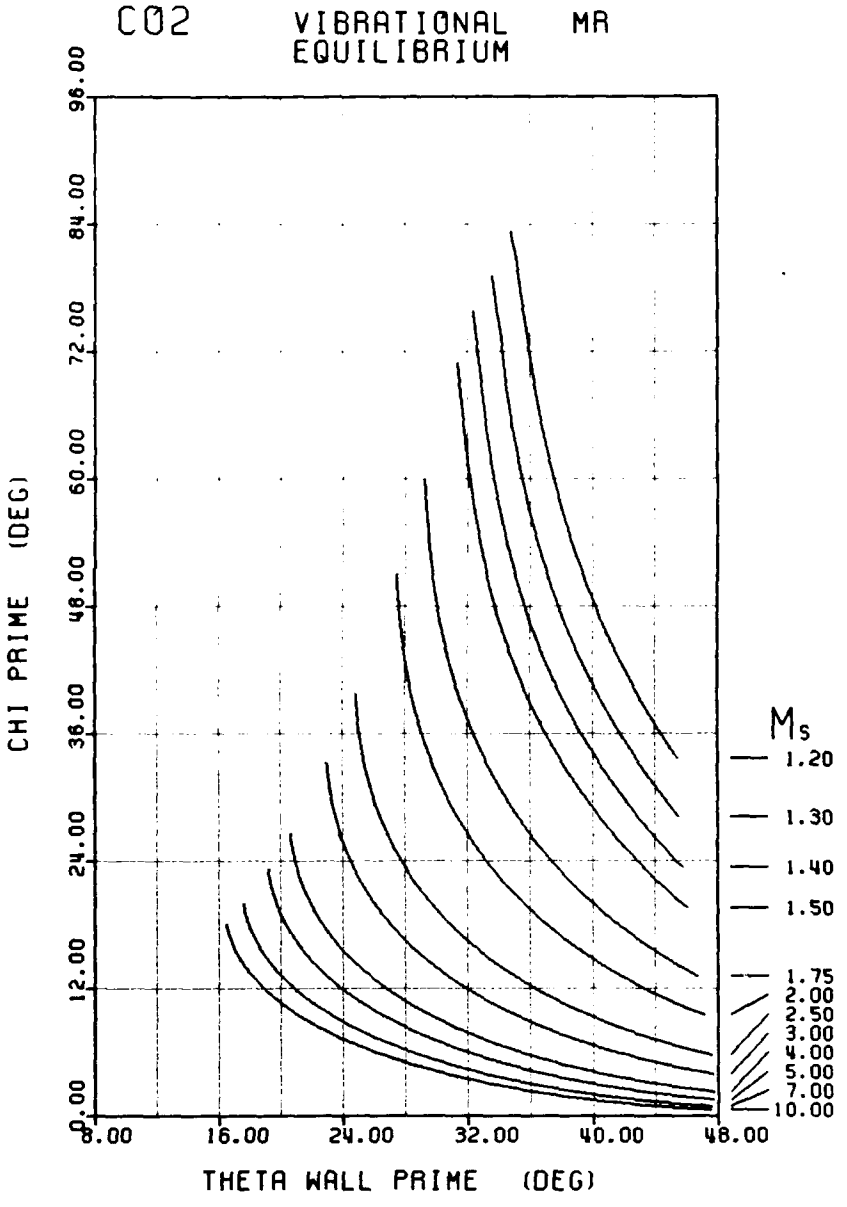

C02 VIBRATIONAL EQUILIBRIUM MR
PHI3 (DEG)
THETA WALL PRIME (DEG)
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
8.00
16.00
24.00
32.00
40.00
48.00
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms

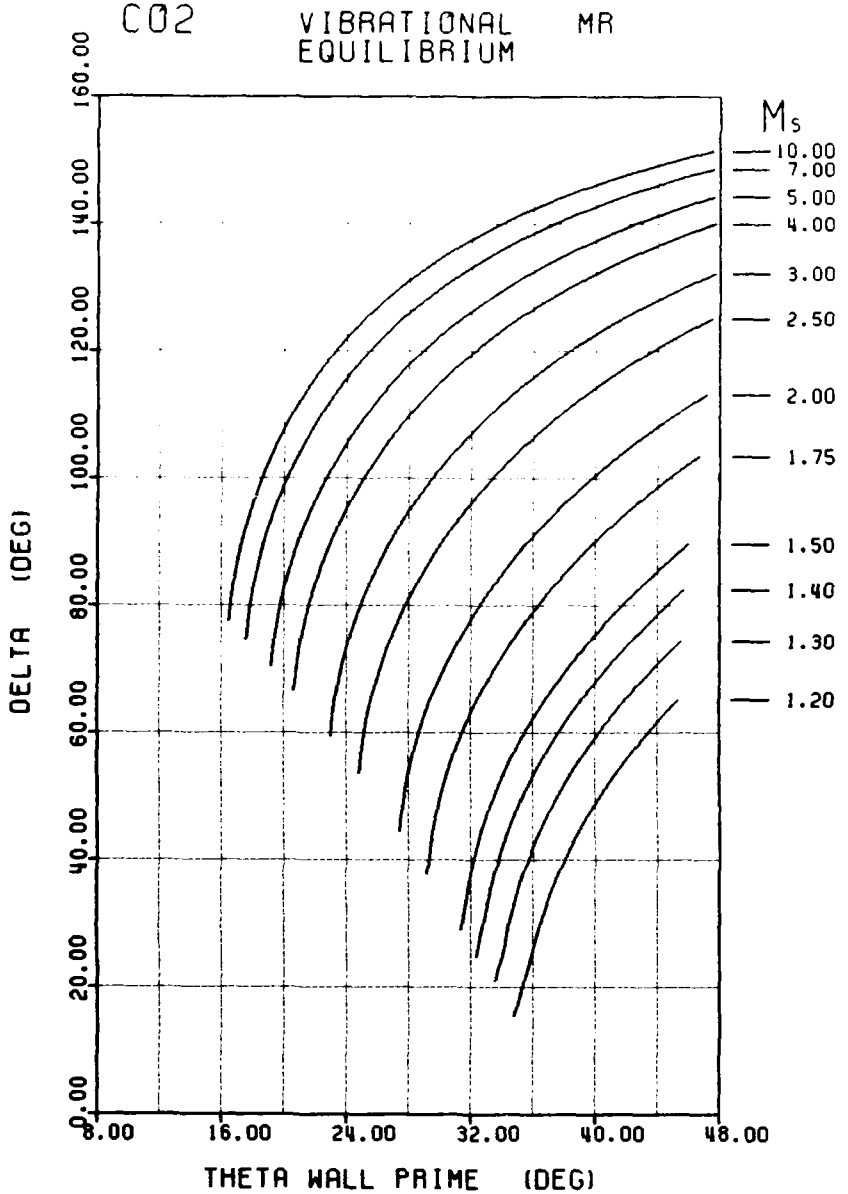

C02 VIBRATIONAL EQUILIBRIUM MR
THETA1 (DEG)
THETA WALL PRIME (DEG)
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

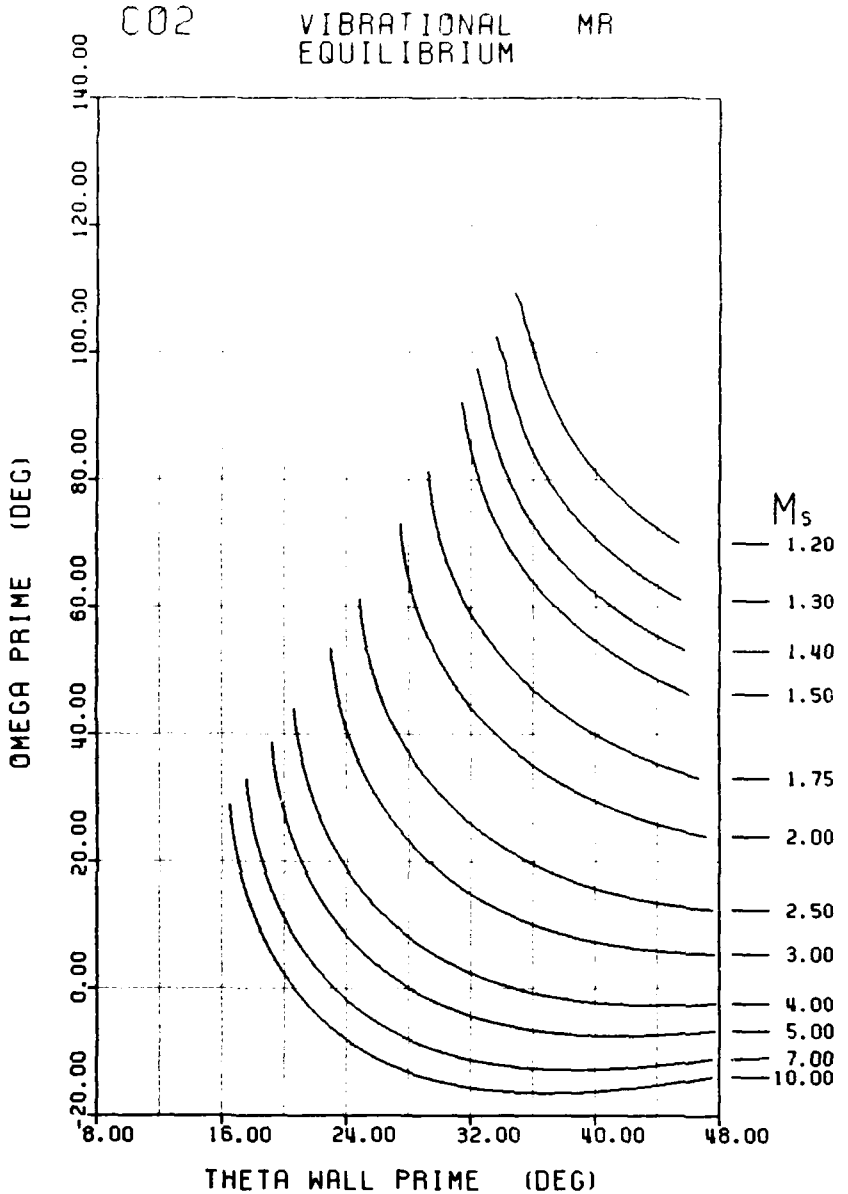

C02 VIBRATIONAL EQUILIBRIUM MR
THETA2 (DEG)
THETA WALL PRIME (DEG)
Ms
2.00
1.75
2.50
3.00
1.50
4.00
1.40
5.00
7.00
1.30
10.00
1.20
18.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
8.00
16.00
24.00
32.00
40.00
48.00

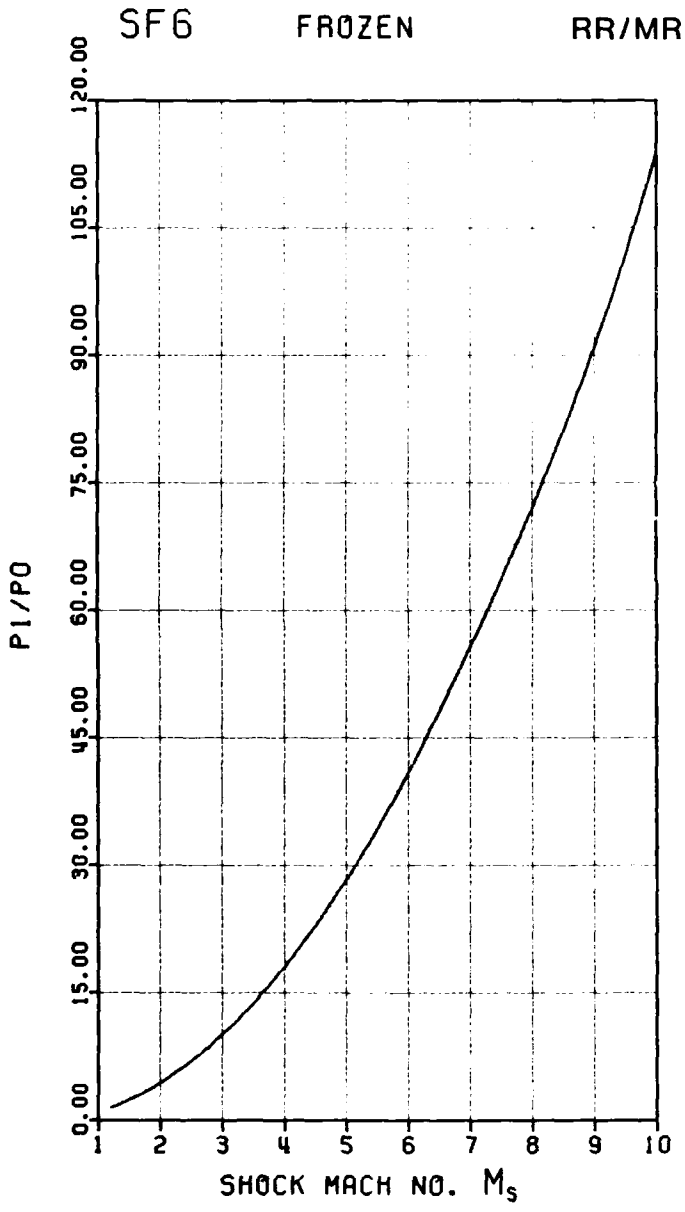

C02 VIBRATIONAL EQUILIBRIUM MR
THETA3 (DEG)
THETA WALL PRIME (DEG)
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00

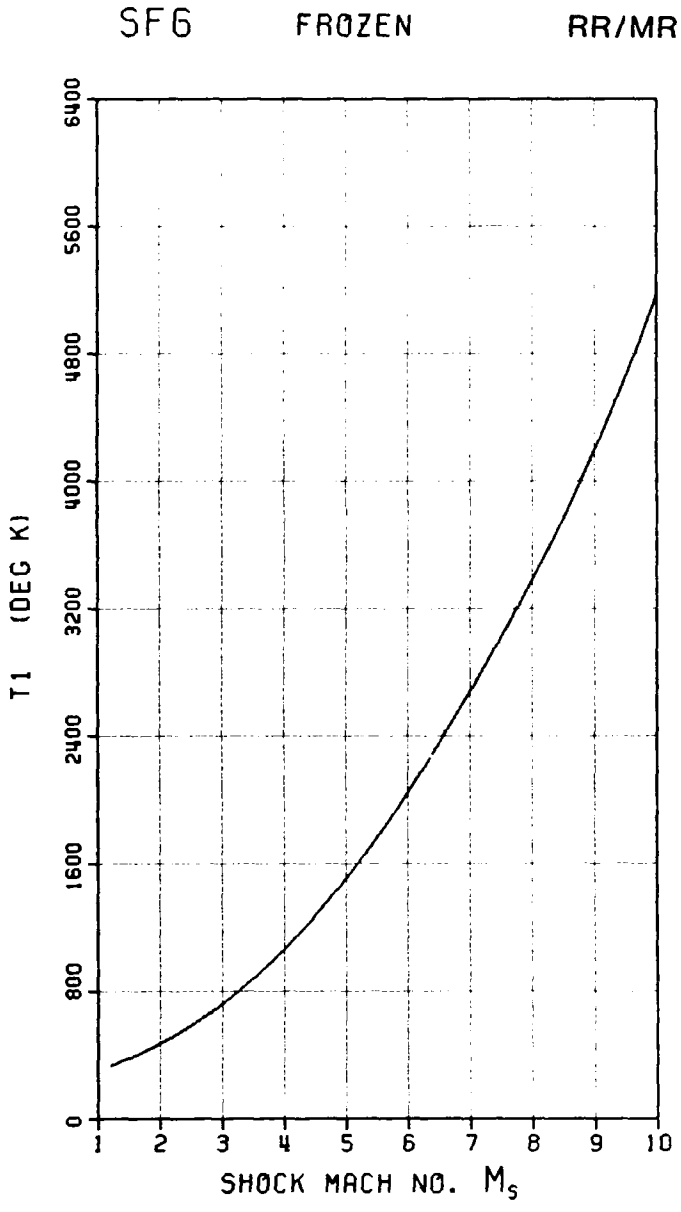

C02 VIBRATIONAL EQUILIBRIUM MR
CHI (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
8.00
16.00
24.00
32.00
40.00
48.00

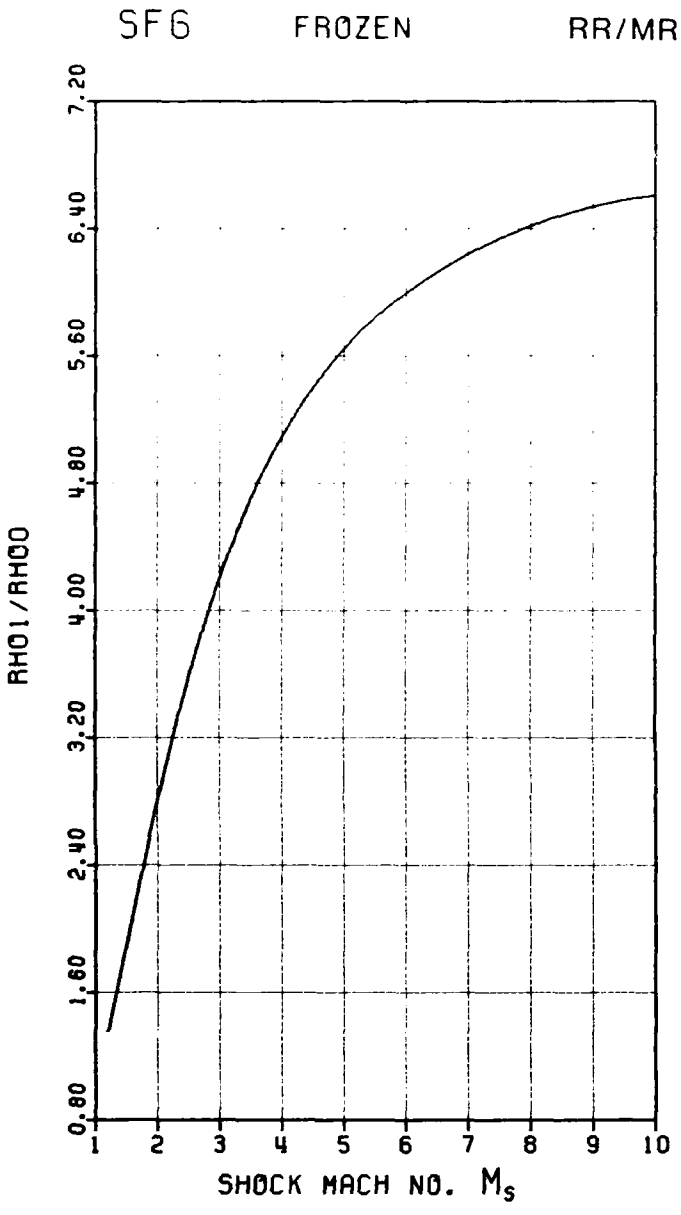

C02 VIBRATIONAL EQUILIBRIUM MR
CHI PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
8.00
16.00
24.00
32.00
40.00
48.00

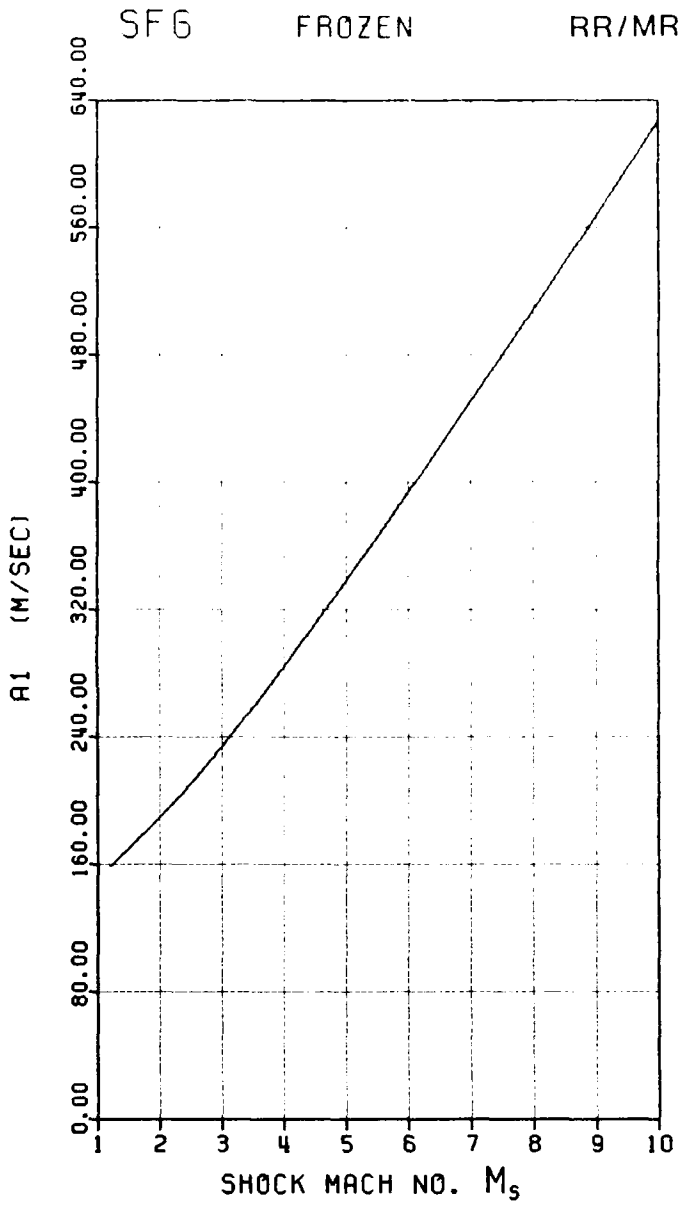

CO2 VIBRATIONAL EQUILIBRIUM MR
DELTA (DEG)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
8.00
16.00
24.00
32.00
40.00
48.00

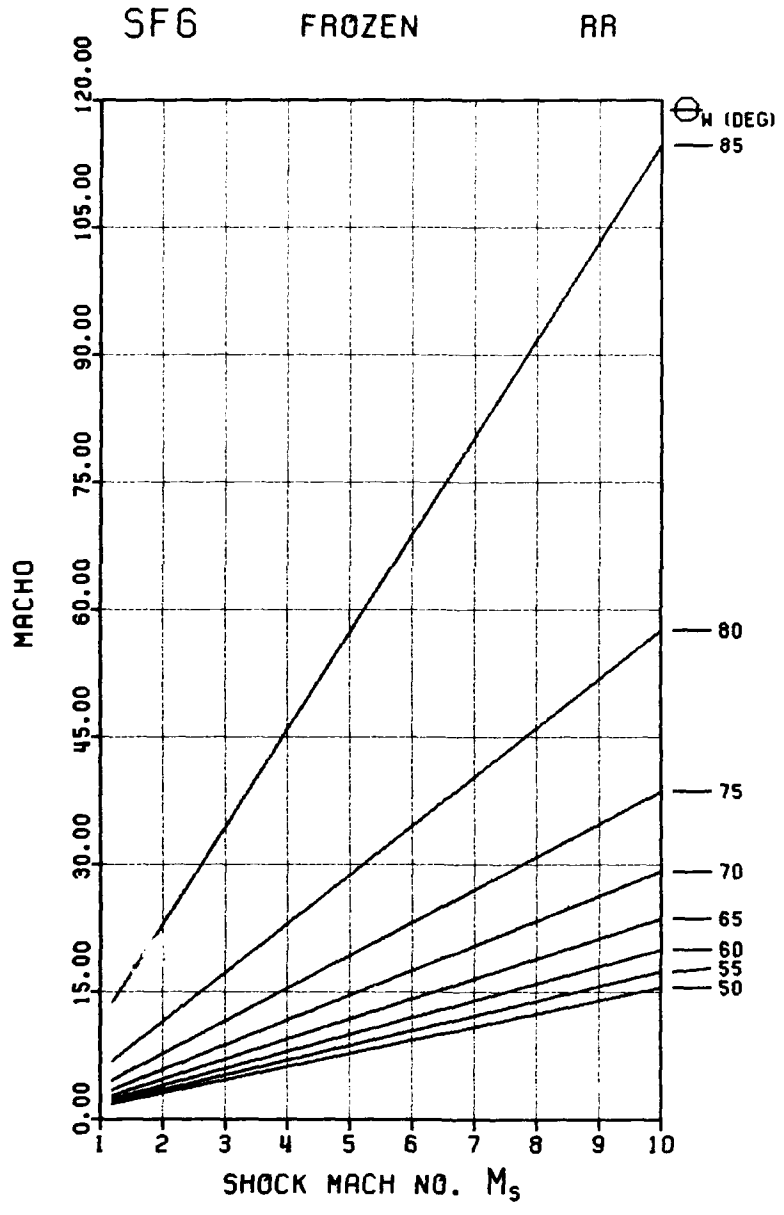

CO2 VIBRATIONAL EQUILIBRIUM MR
OMEGA PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
8.00
16.00
24.00
32.00
40.00
48.00

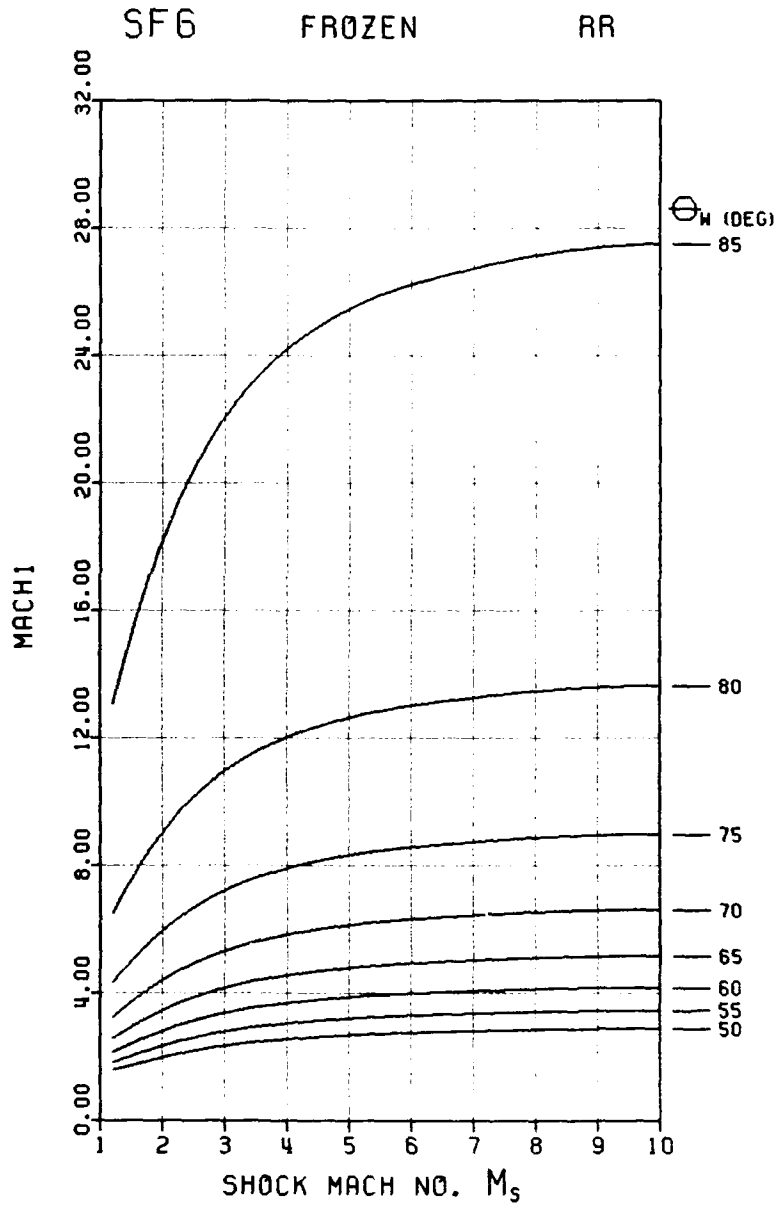

SF6 FROZEN RR/MR
P1/P0
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

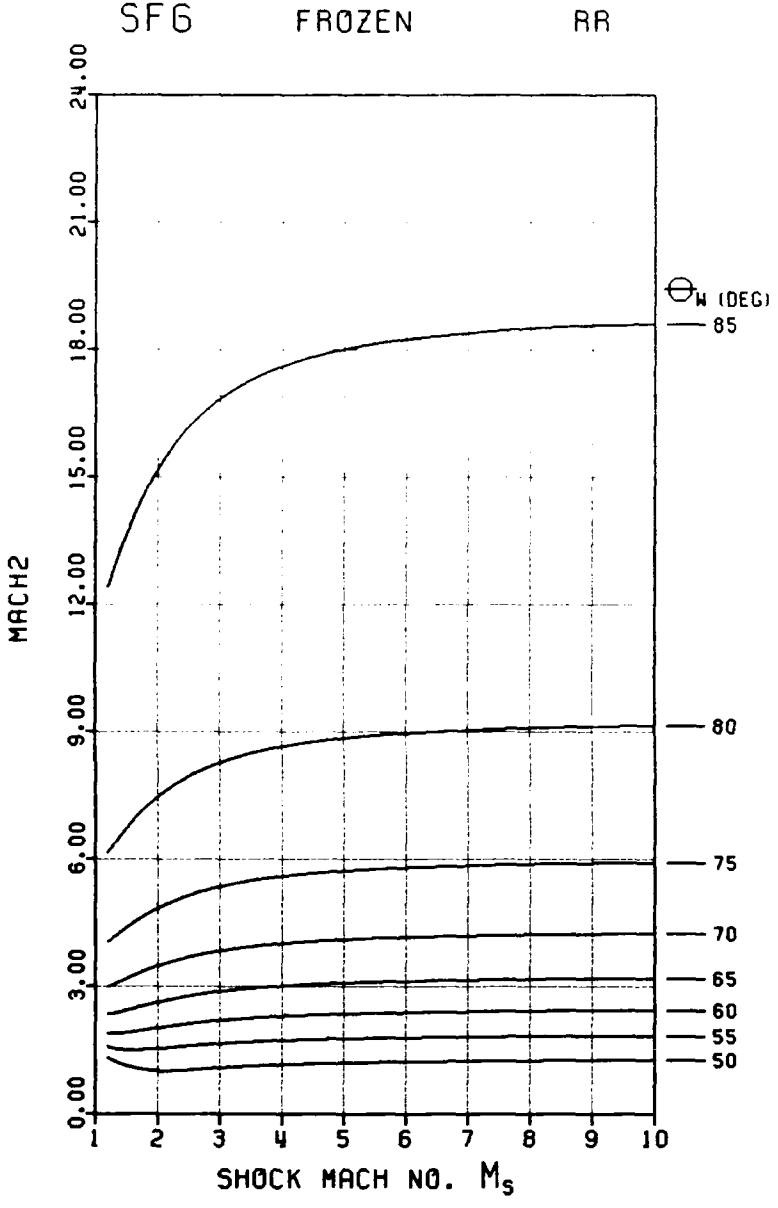

SF6 FROZEN RR/MR
T1 (DEG K)
0
800
1600
2400
3200
4000
4800
5600
6400
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

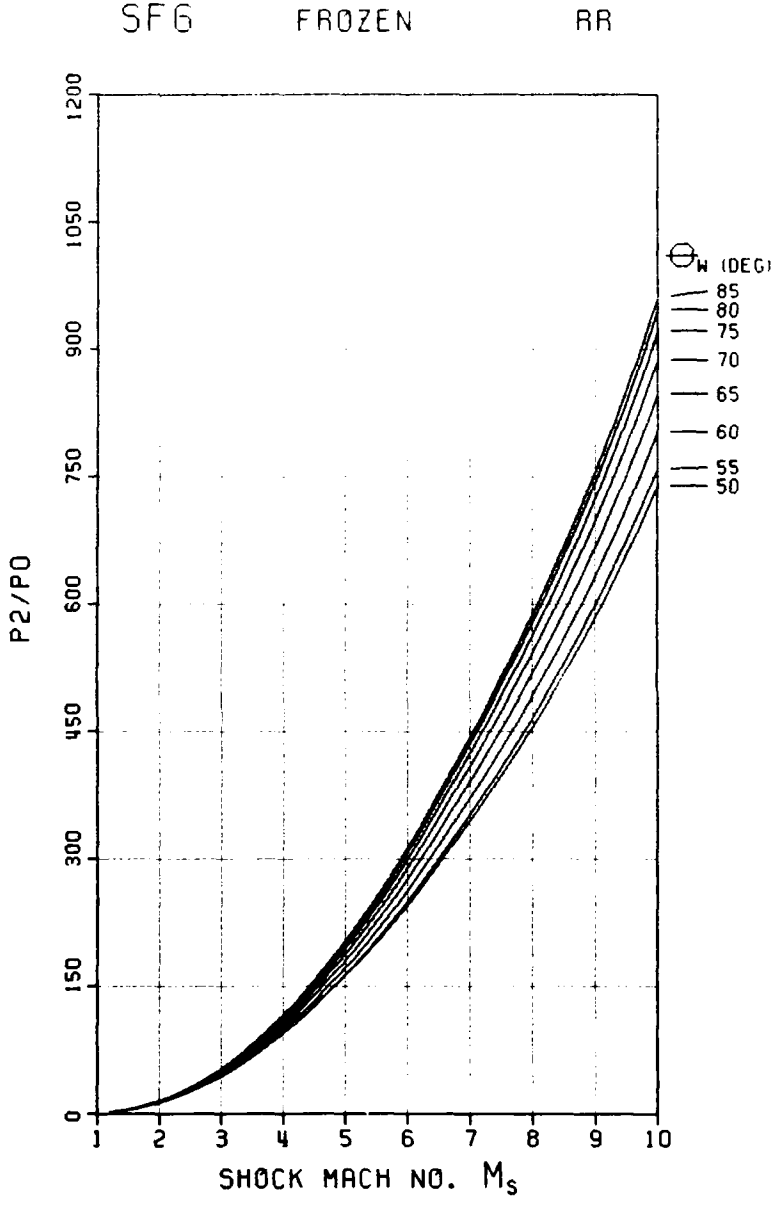

SF6 FROZEN RR/MR
RHO1/RHOO
0.80
1.60
2.40
3.20
4.00
4.80
5.60
6.40
7.20
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

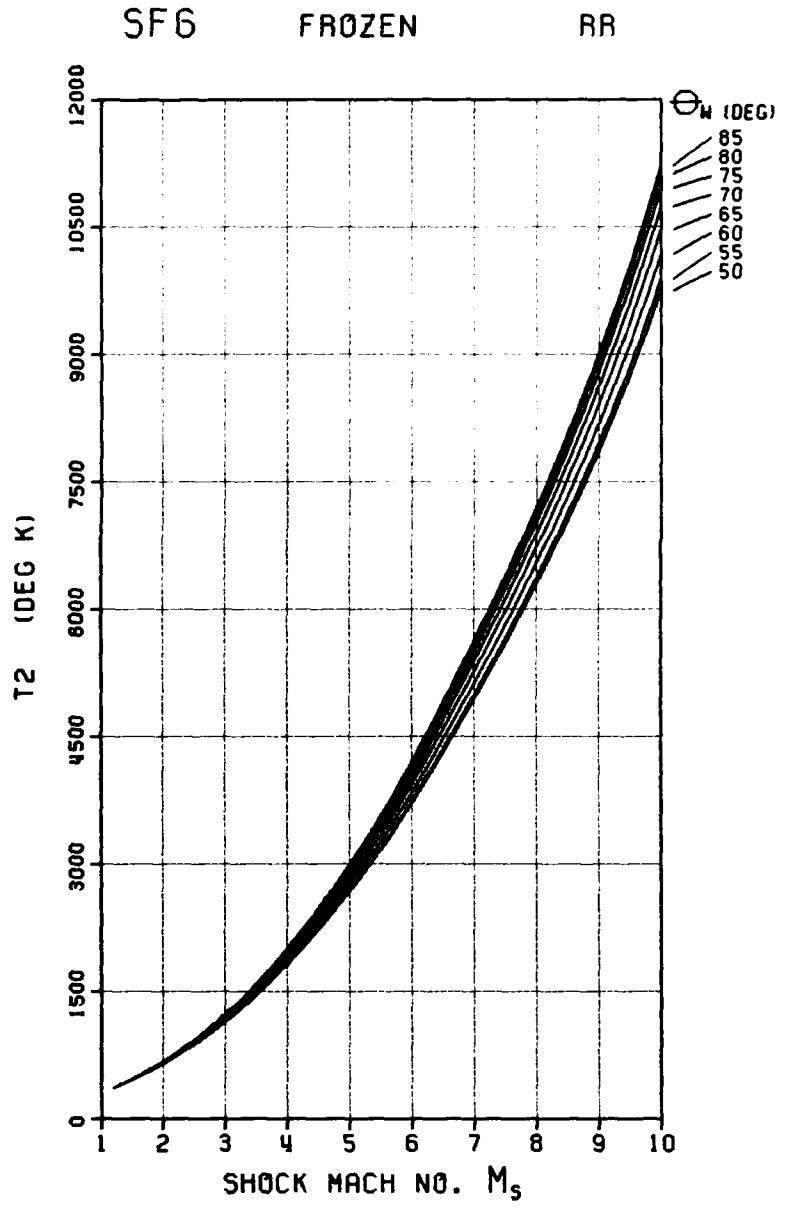

SF6 FROZEN RR/MR
A1 (M/SEC)
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

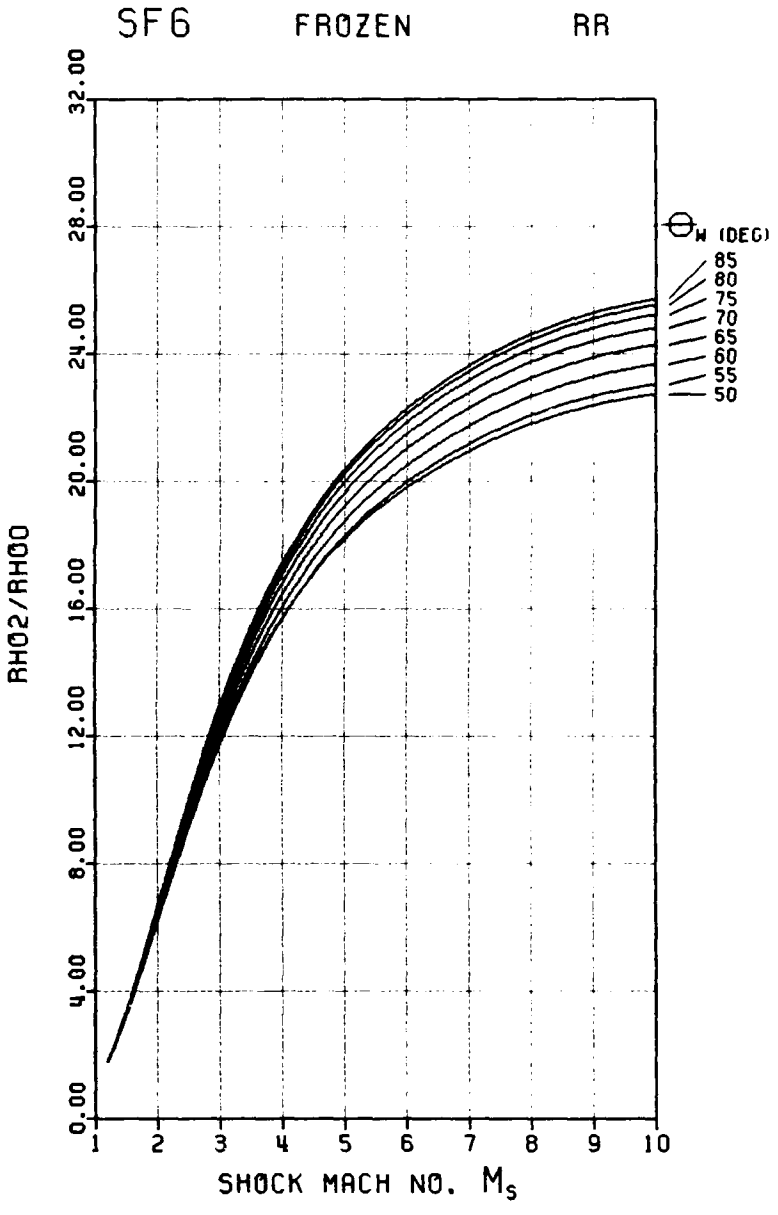

SF6 FROZEN RR
MACH0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1
2
3
4
5
6
7
8
9
10

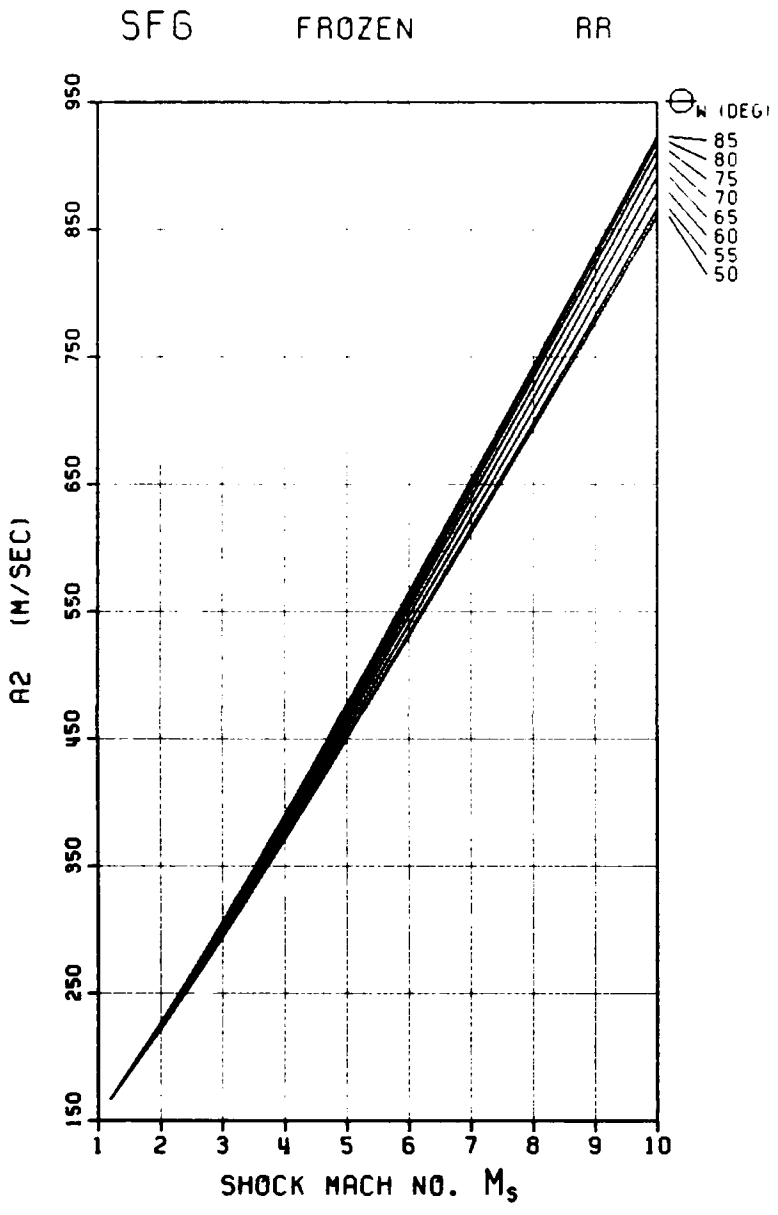

SF6 FROZEN RR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
1
2
3
4
5
6
7
8
9
10

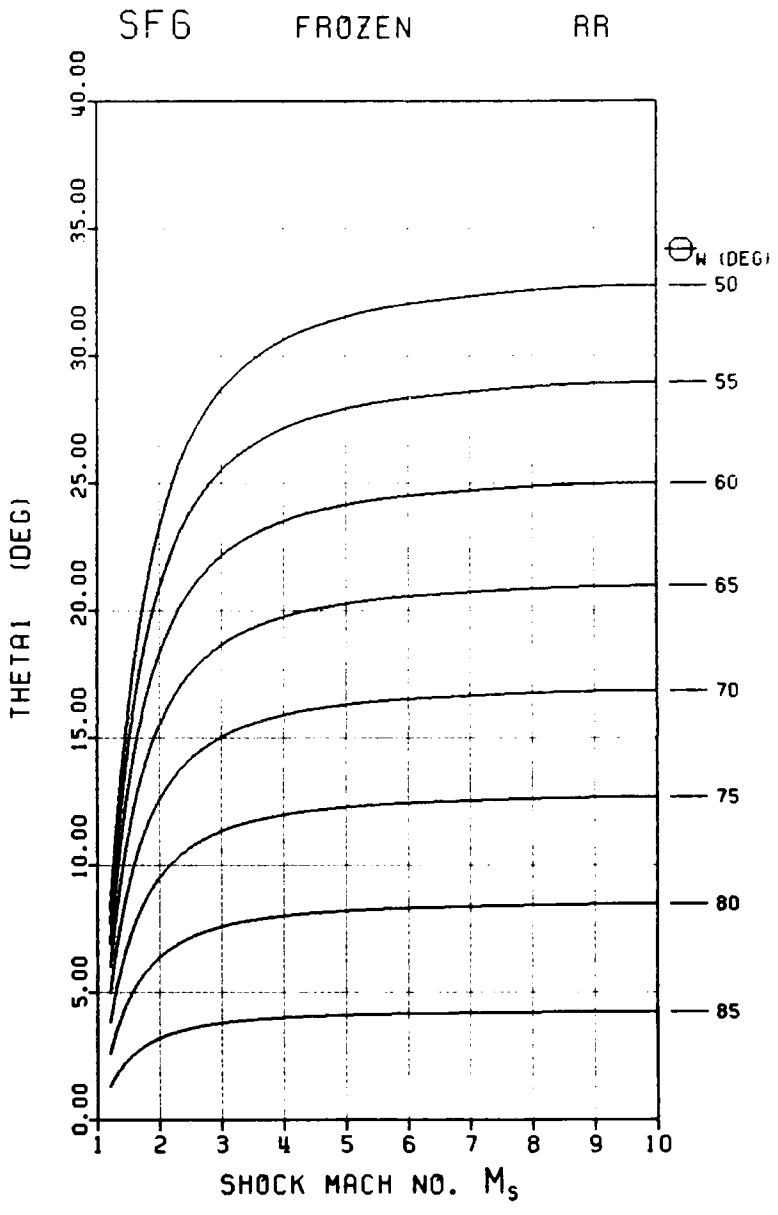

SF6 FROZEN RR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
1
2
3
4
5
6
7
8
9
10

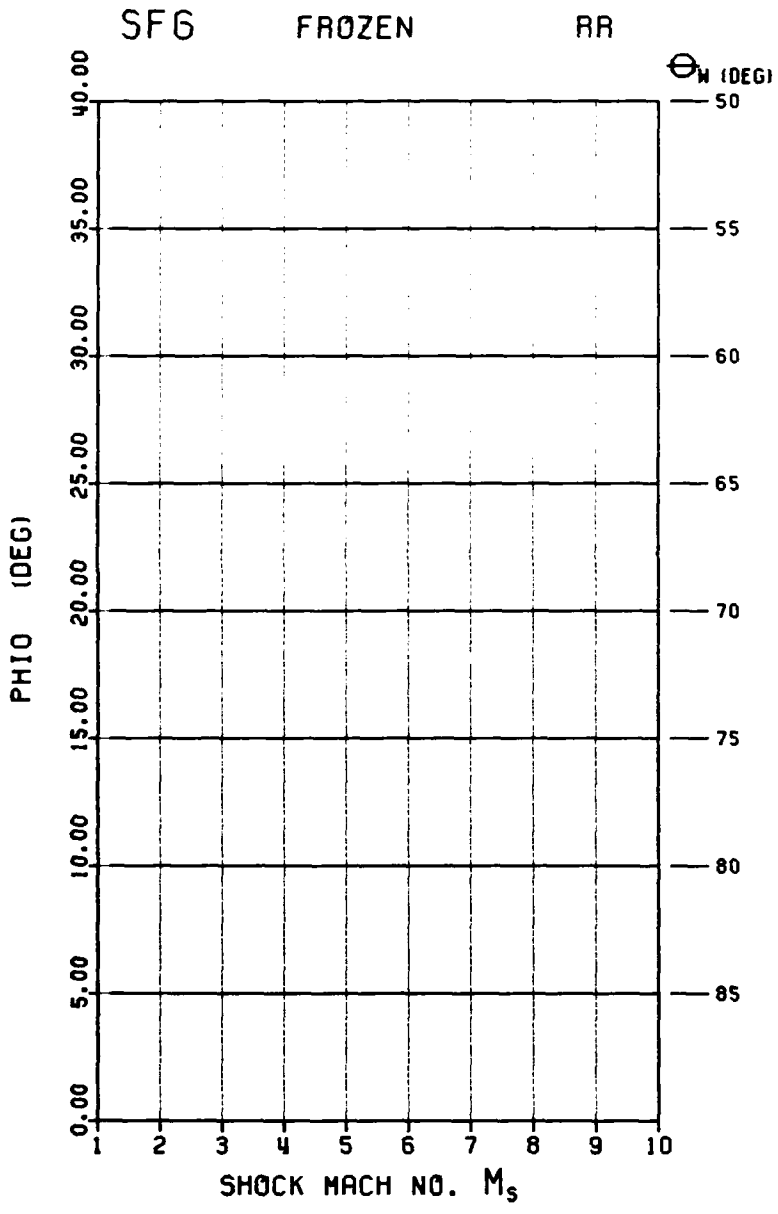

SF6 FROZEN RR
P2/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0
150
300
450
600
750
900
1050
1200
1
2
3
4
5
6
7
8
9
10

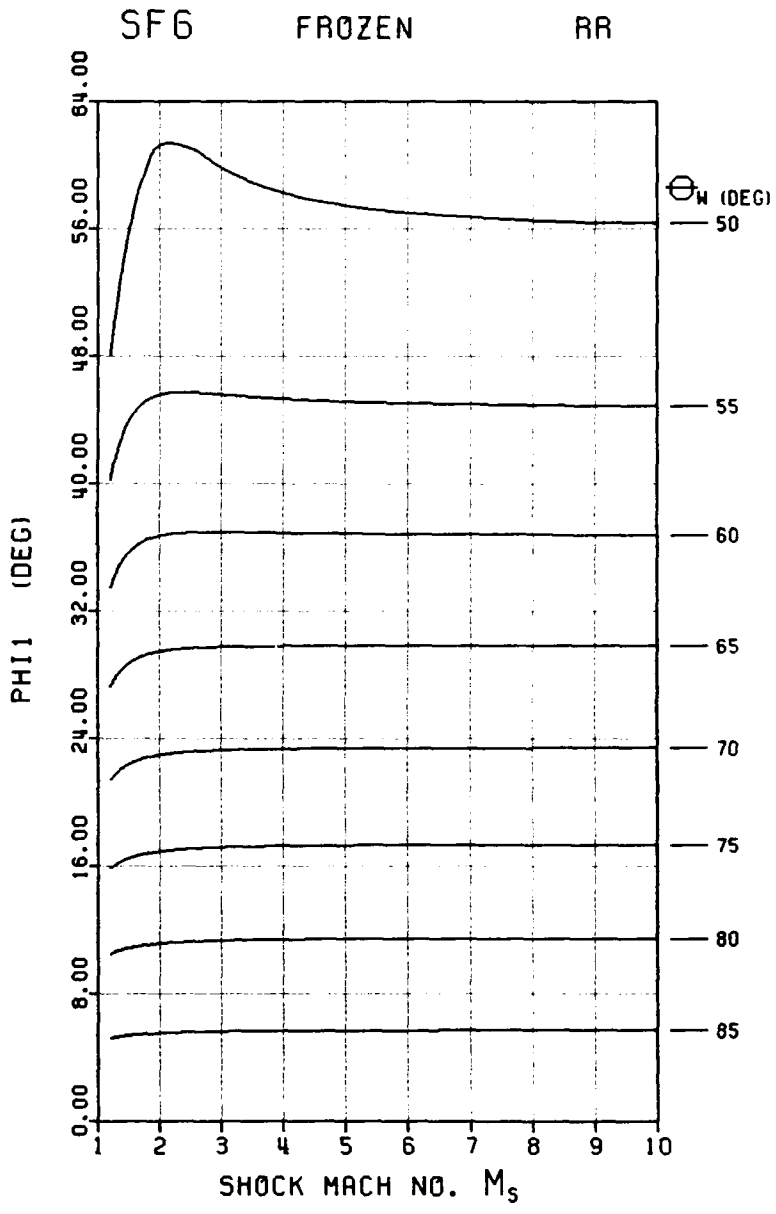

SF6 FROZEN RR
T2 (DEG K)
0
1500
3000
4500
6000
7500
9000
10500
12000
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

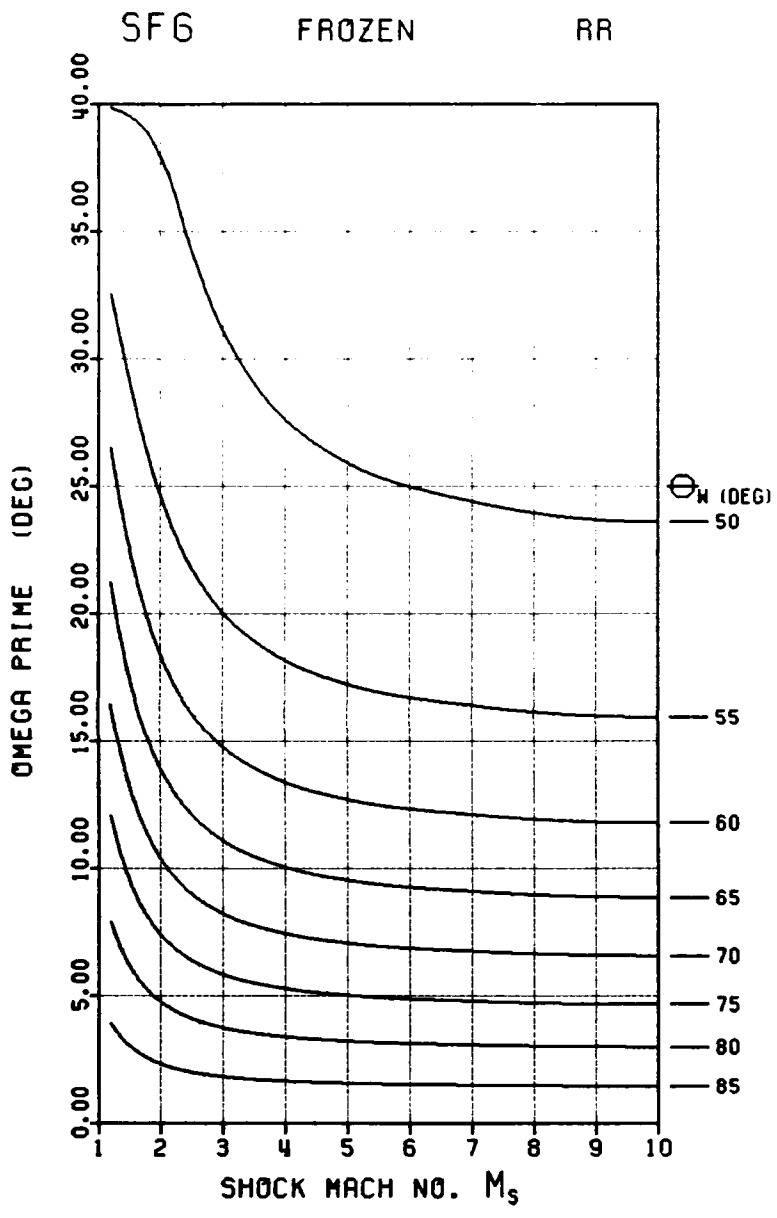

SF6 FROZEN RR
RH02/RH00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

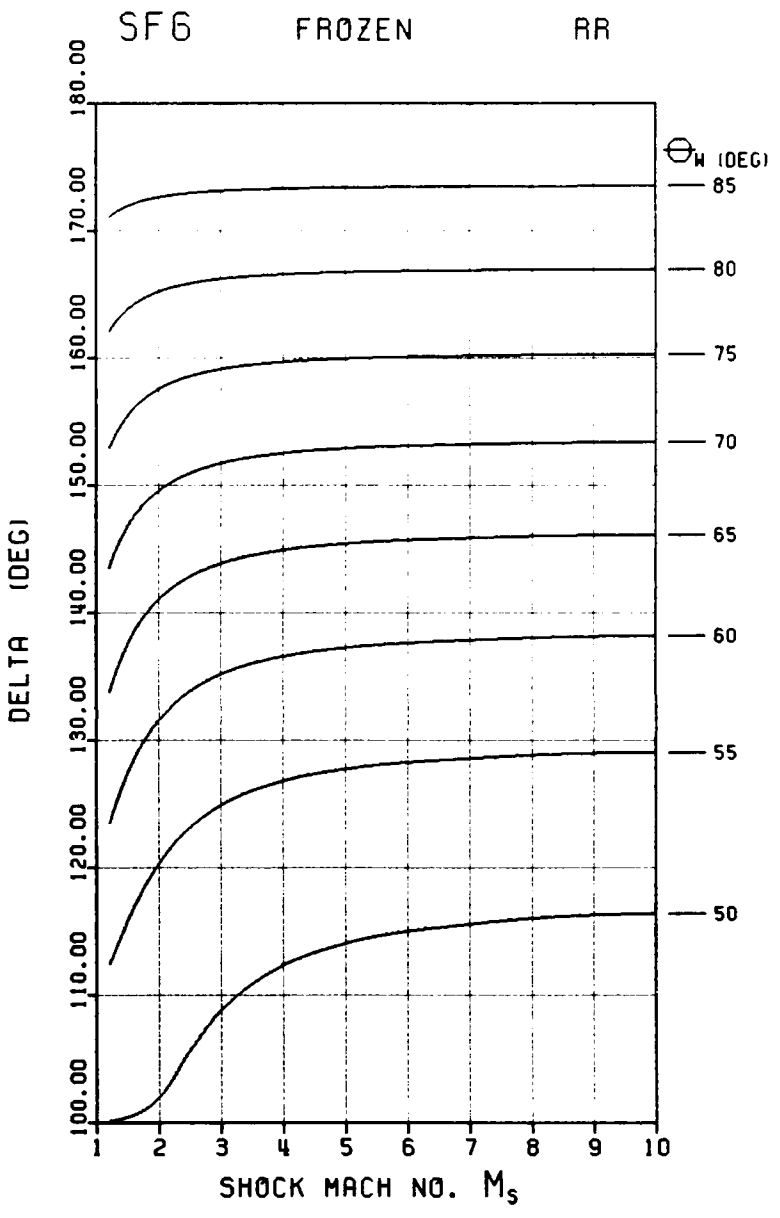

SF6 FROZEN RR
A2 (M/SEC)
150
250
350
450
550
650
750
850
950
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

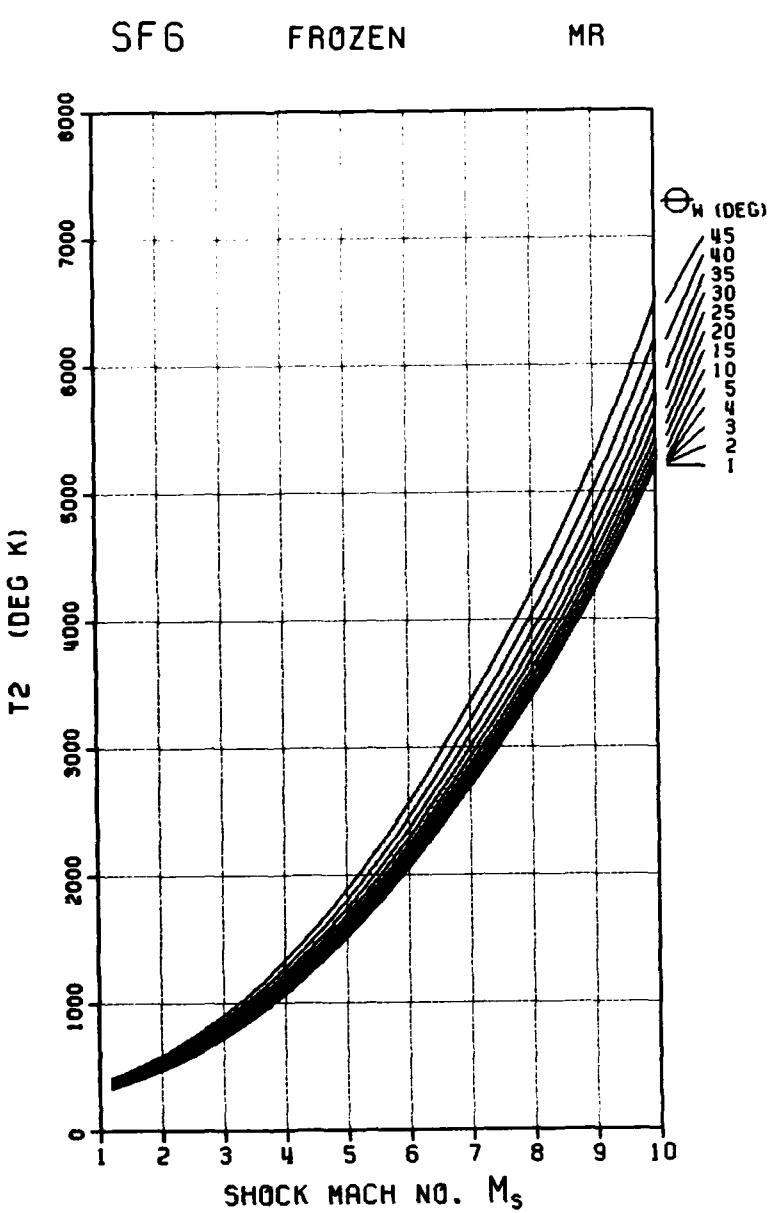

SF6 FROZEN RR
THETA1 (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
55
60
65
70
75
80
85

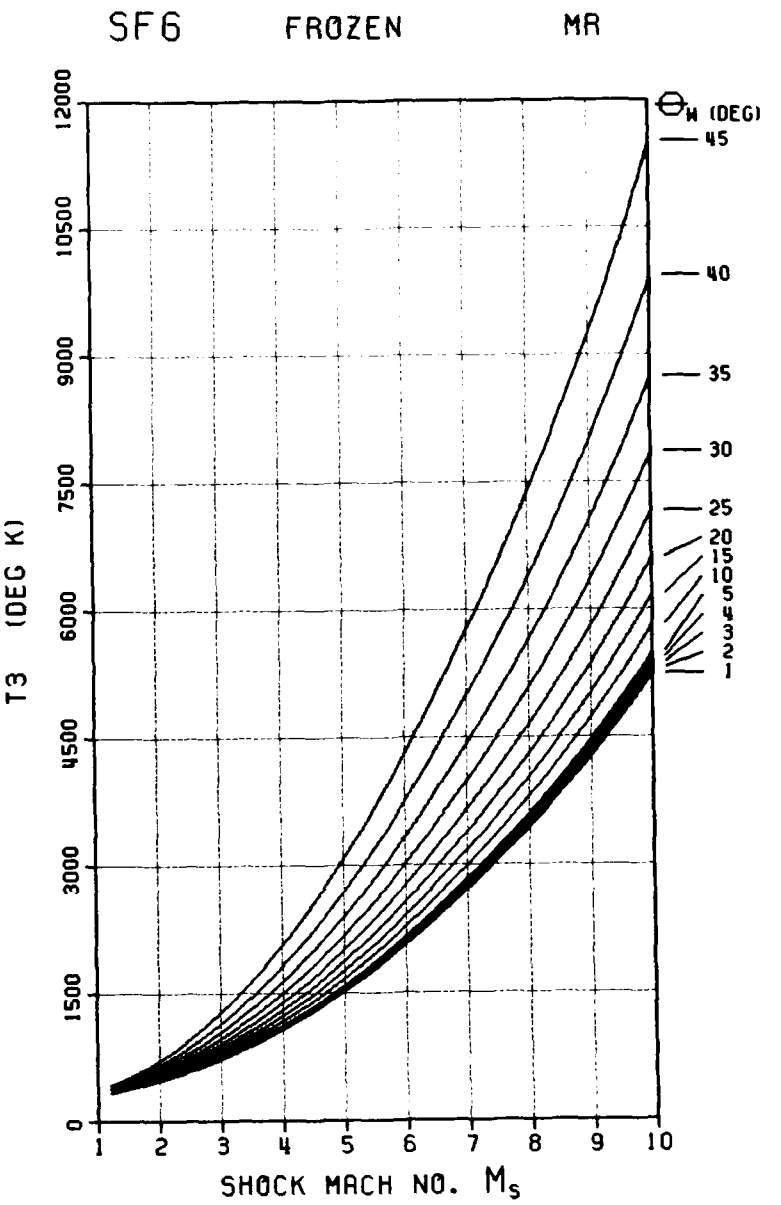

SF6 FROZEN RR
PHI0 (DEG)
Θ_W (DEG)
50
55
60
65
70
75
80
85
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

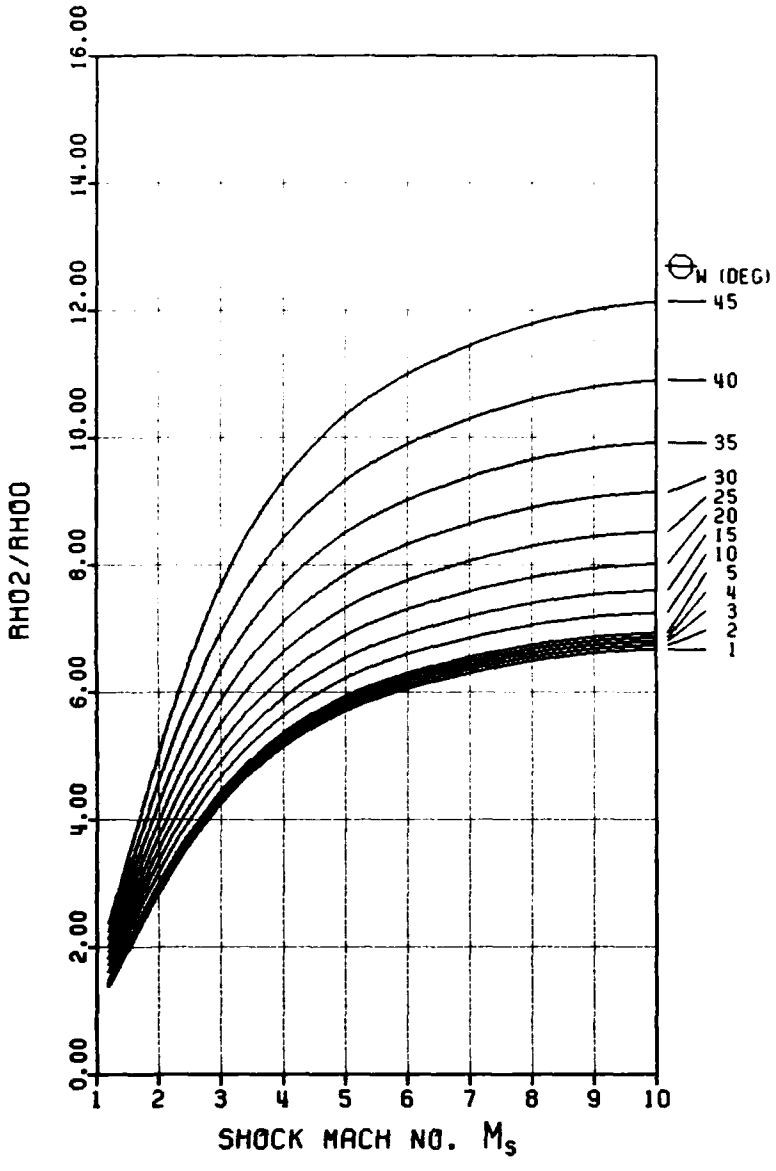

SF6 FROZEN RR
PHI1 (DEG)
Θ_W (DEG)
50
55
60
65
70
75
80
85
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

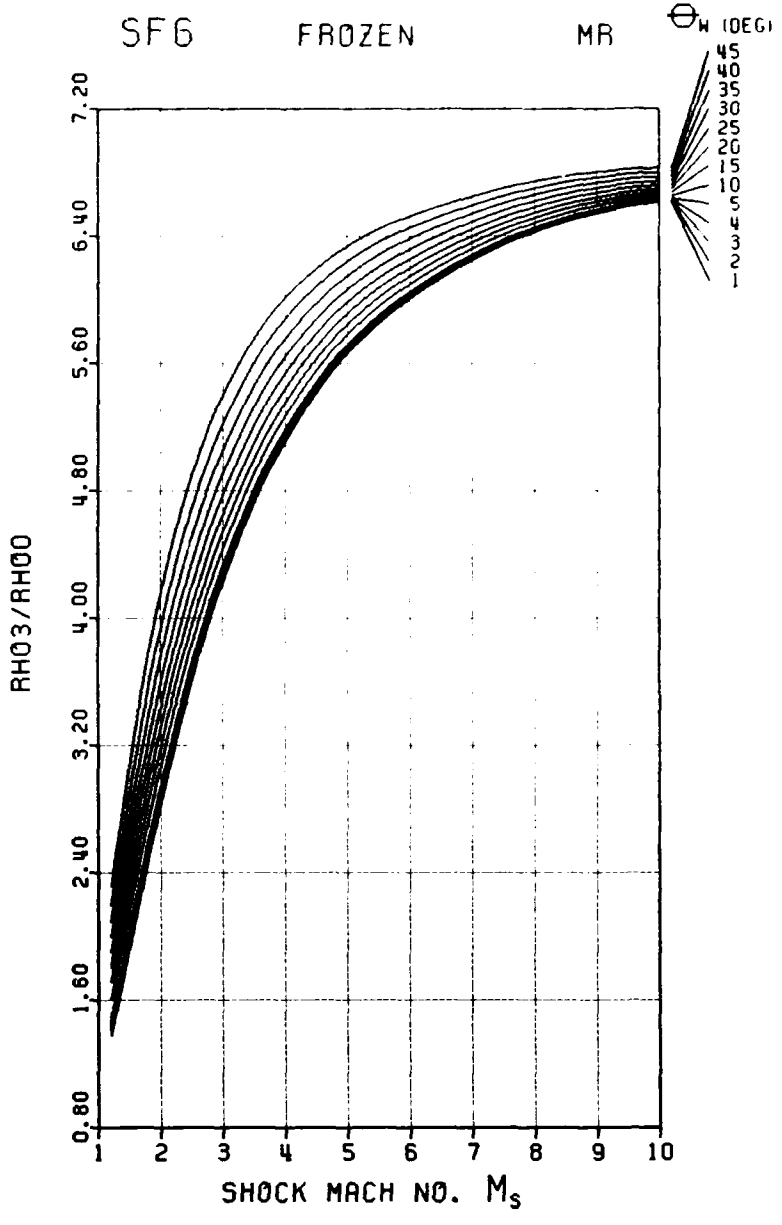

SF6 FROZEN RR
OMEGA PRIME (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
55
60
65
70
75
80
85

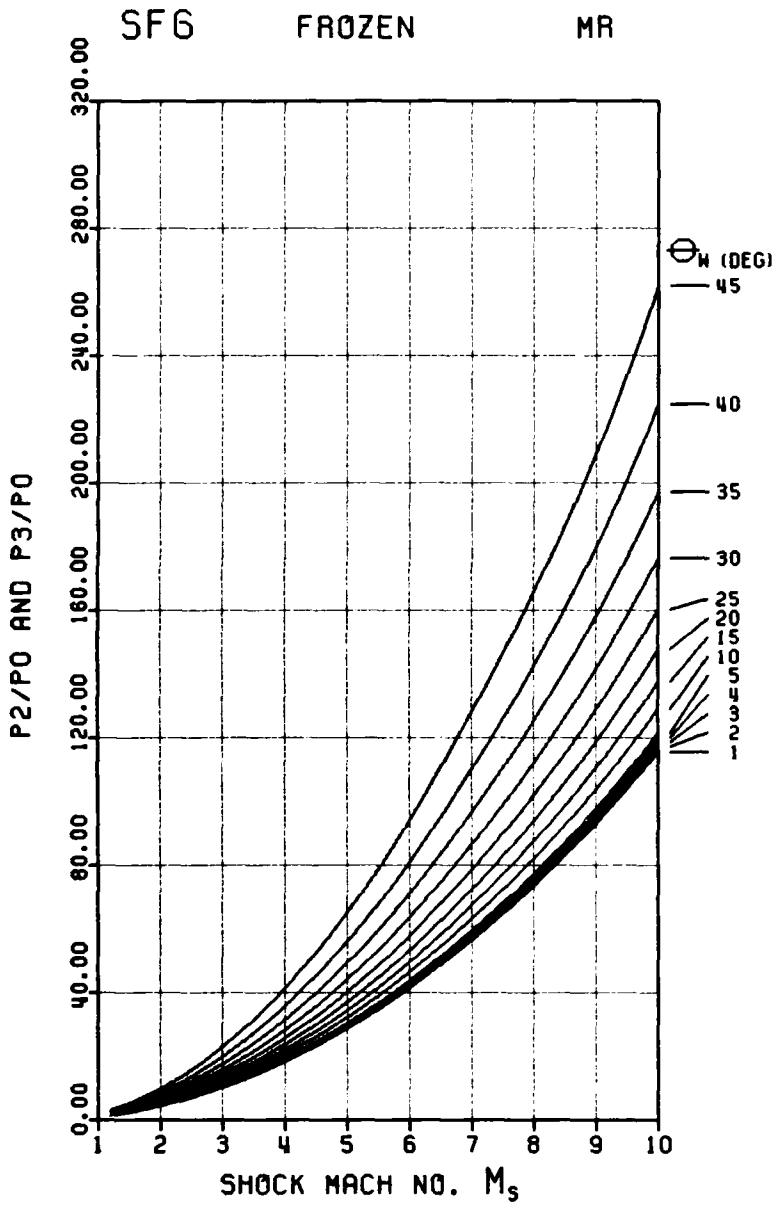

SF6 FROZEN RR
DELTA (DEG)
100.00
110.00
120.00
130.00
140.00
150.00
160.00
170.00
180.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

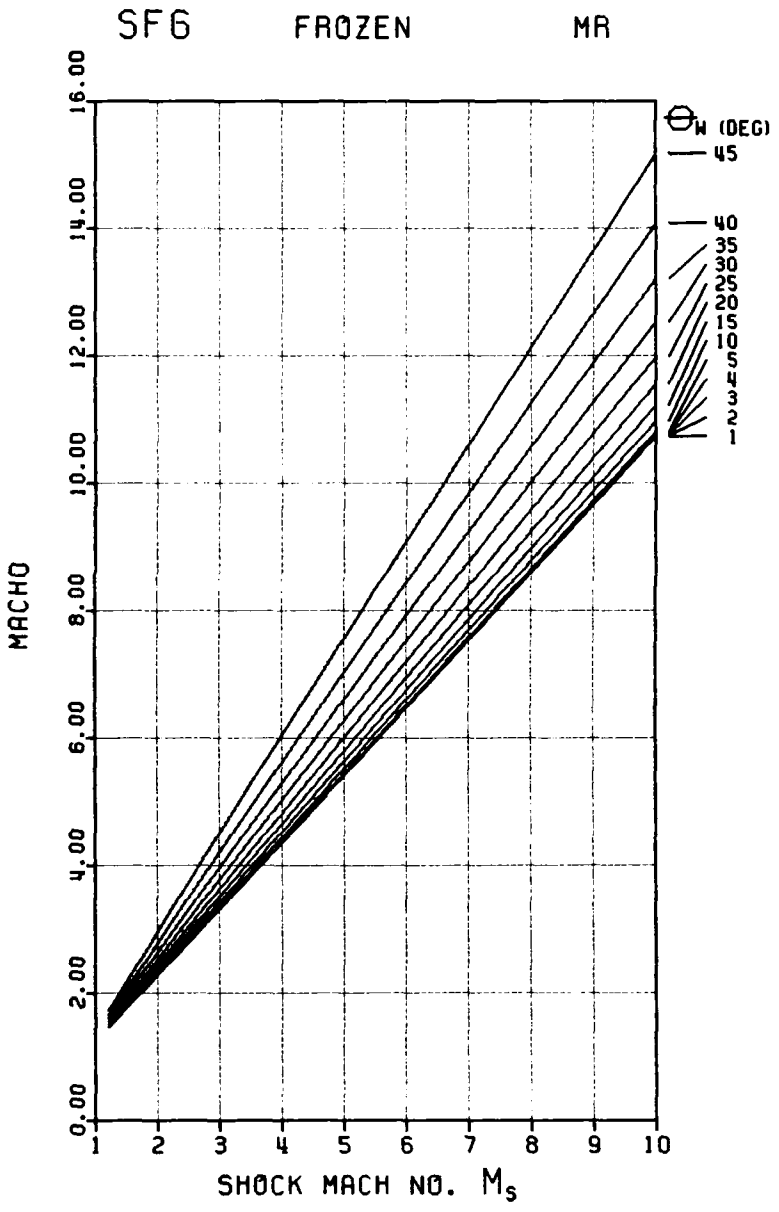

SF6 FROZEN MR
T2 (DEG K)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10

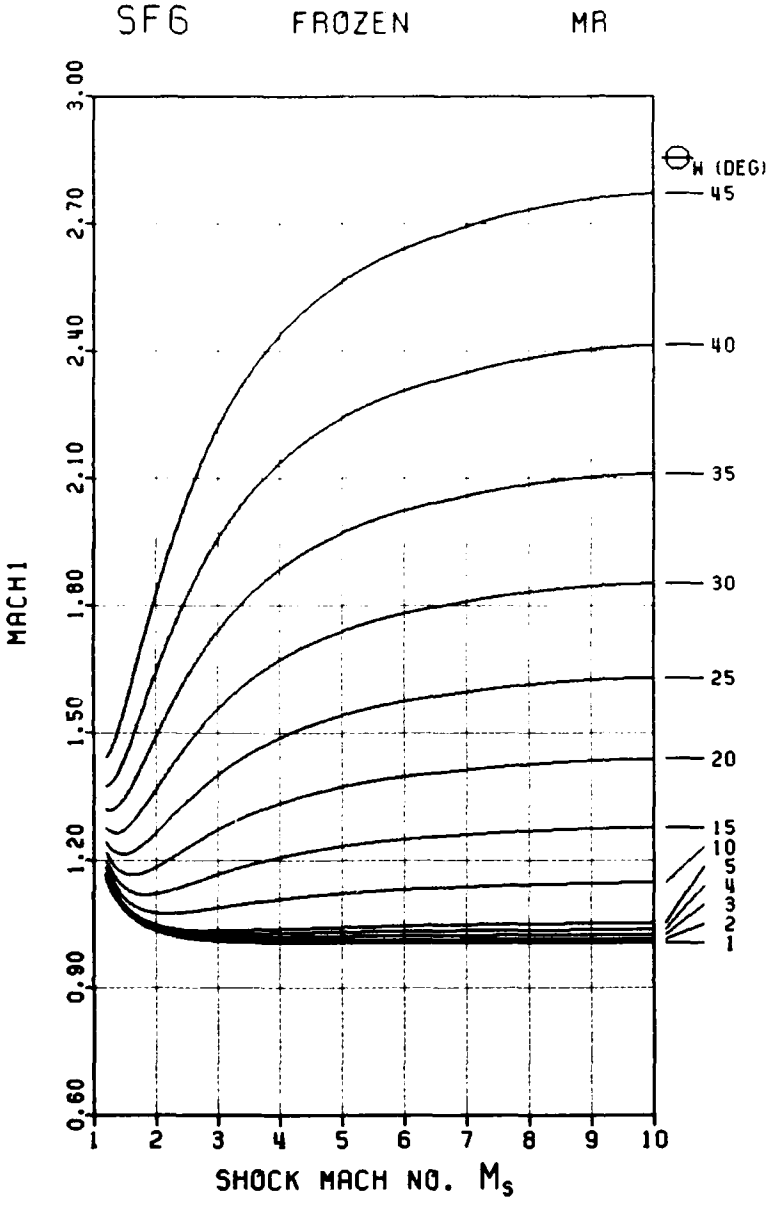

SF6 FROZEN MR
T3 (DEG K)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0
1500
3000
4500
6000
7500
9000
10500
12000
1
2
3
4
5
6
7
8
9
10

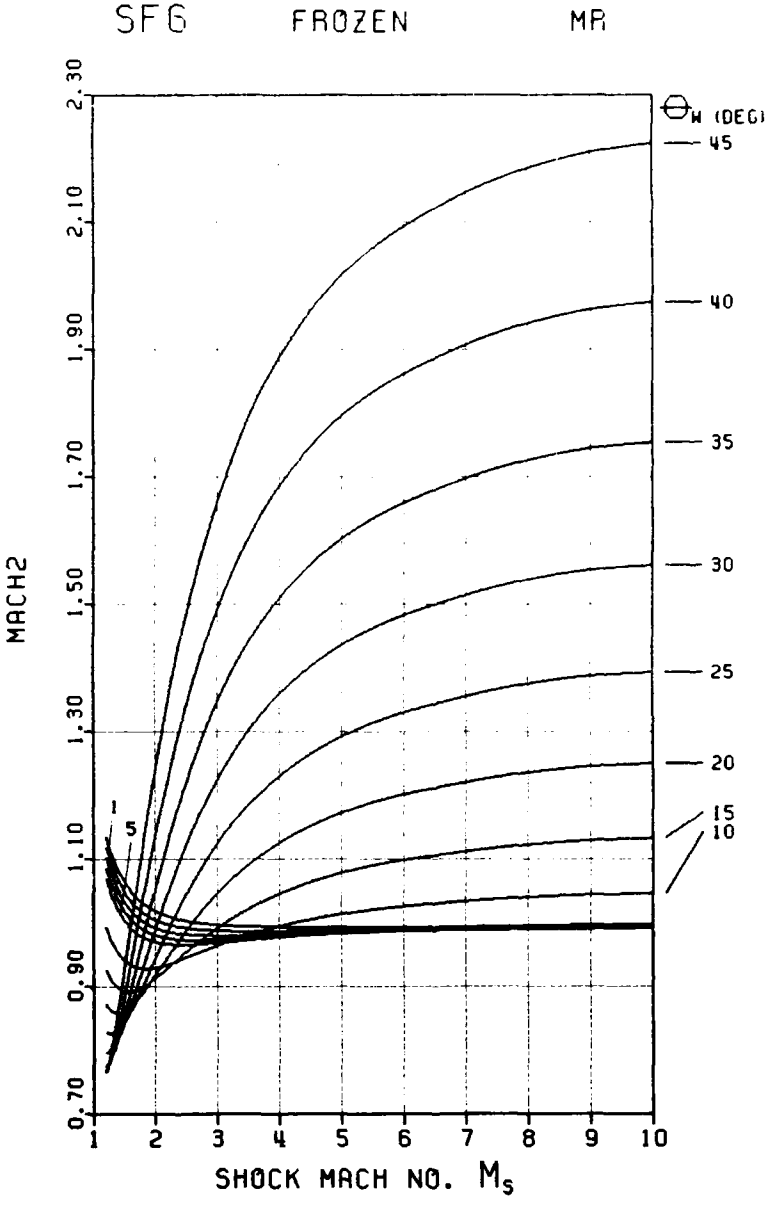

SF6 FROZEN MR
RH02/RH00
SHOCK MACH NO. M_s
Θ_w (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
1
2
3
4
5
6
7
8
9
10

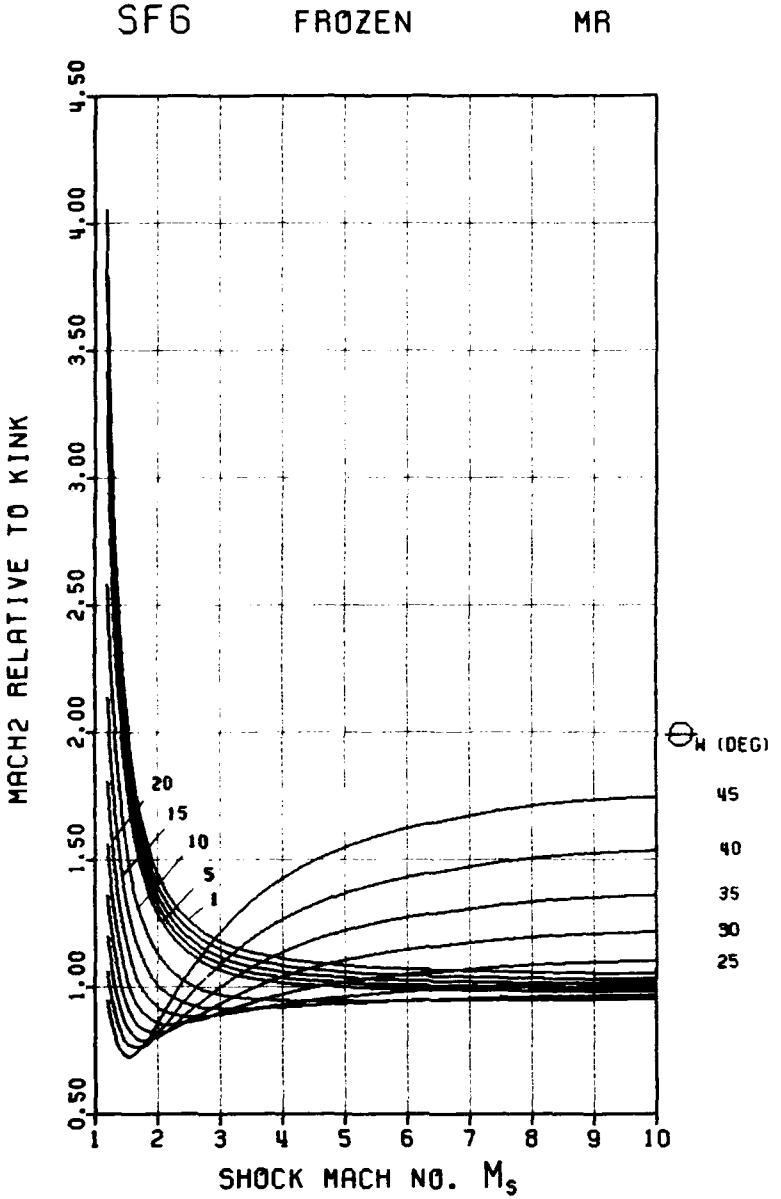

SF6 FROZEN MR
RH03/RH00
SHOCK MACH NO. M_s
Θ_w (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.80
1.60
2.40
3.20
4.00
4.80
5.60
6.40
7.20
1
2
3
4
5
6
7
8
9
10

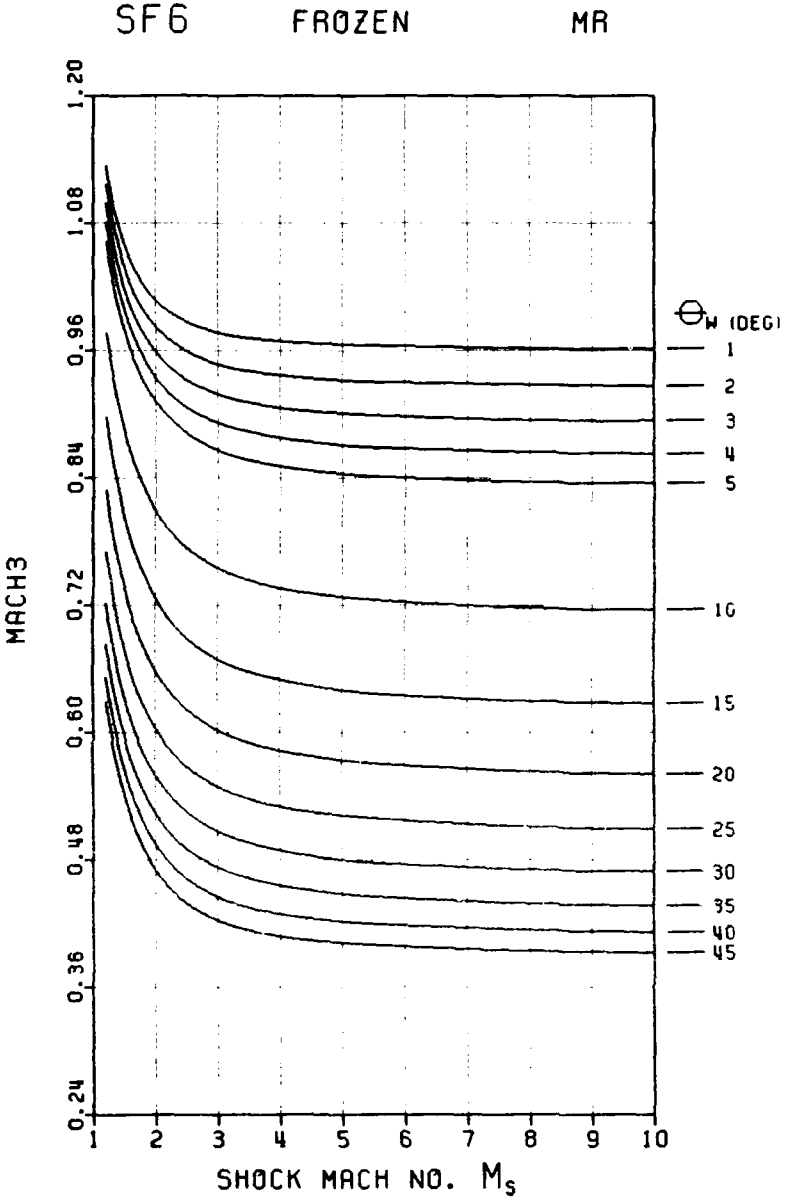

SF6 FROZEN MR
P2/P0 AND P3/P0
320.00
280.00
240.00
200.00
160.00
120.00
80.00
40.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

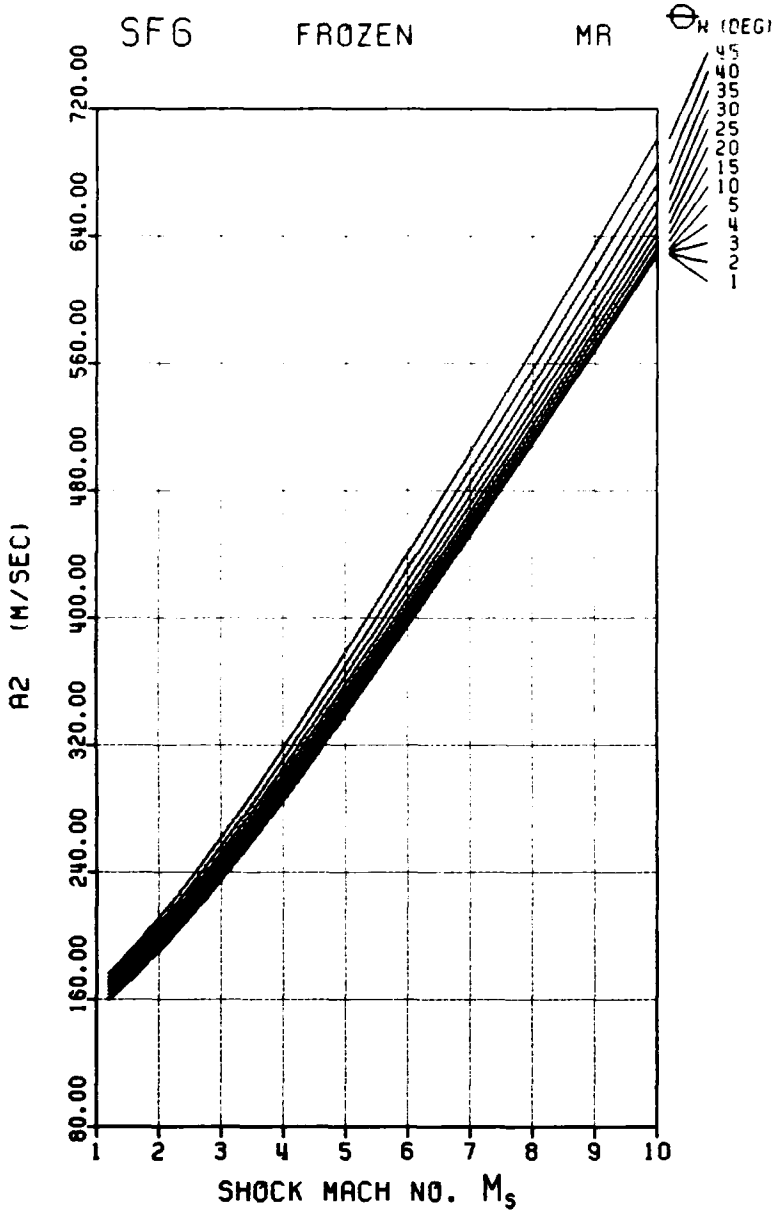

SF6 FROZEN MR
MACH0
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

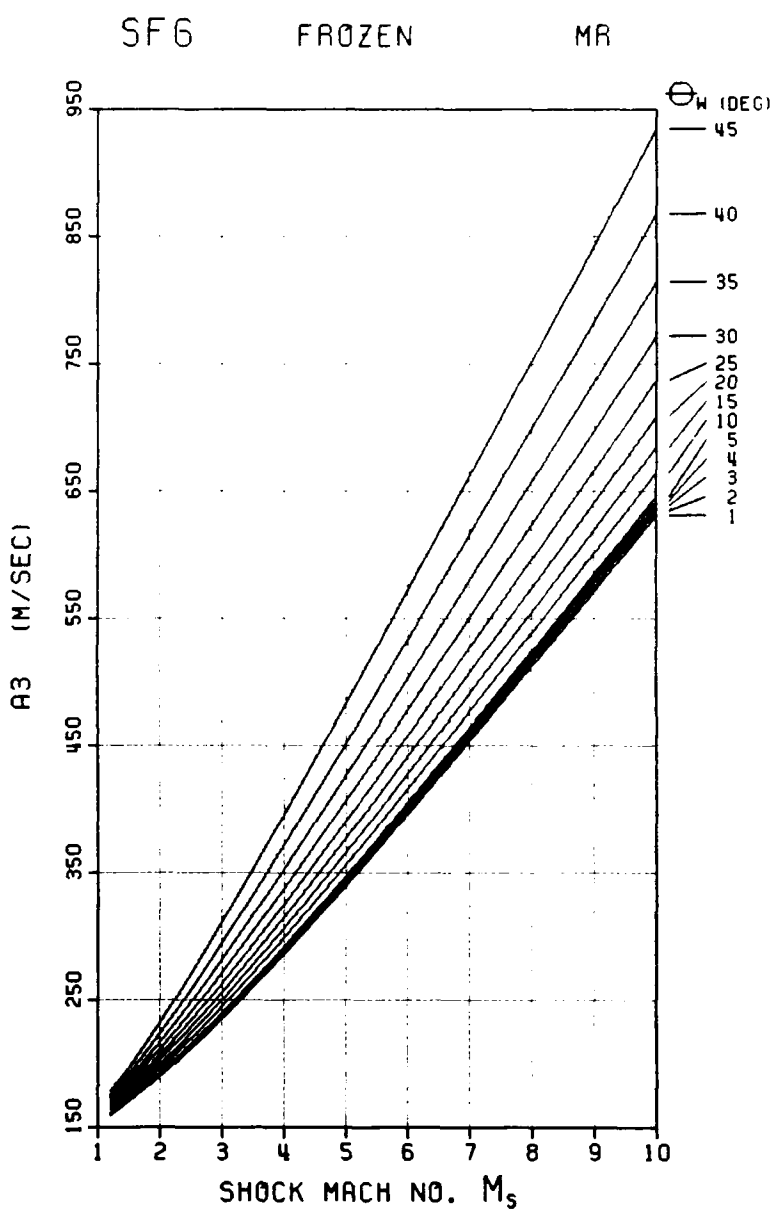

SF6 FROZEN MR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
1
2
3
4
5
6
7
8
9
10

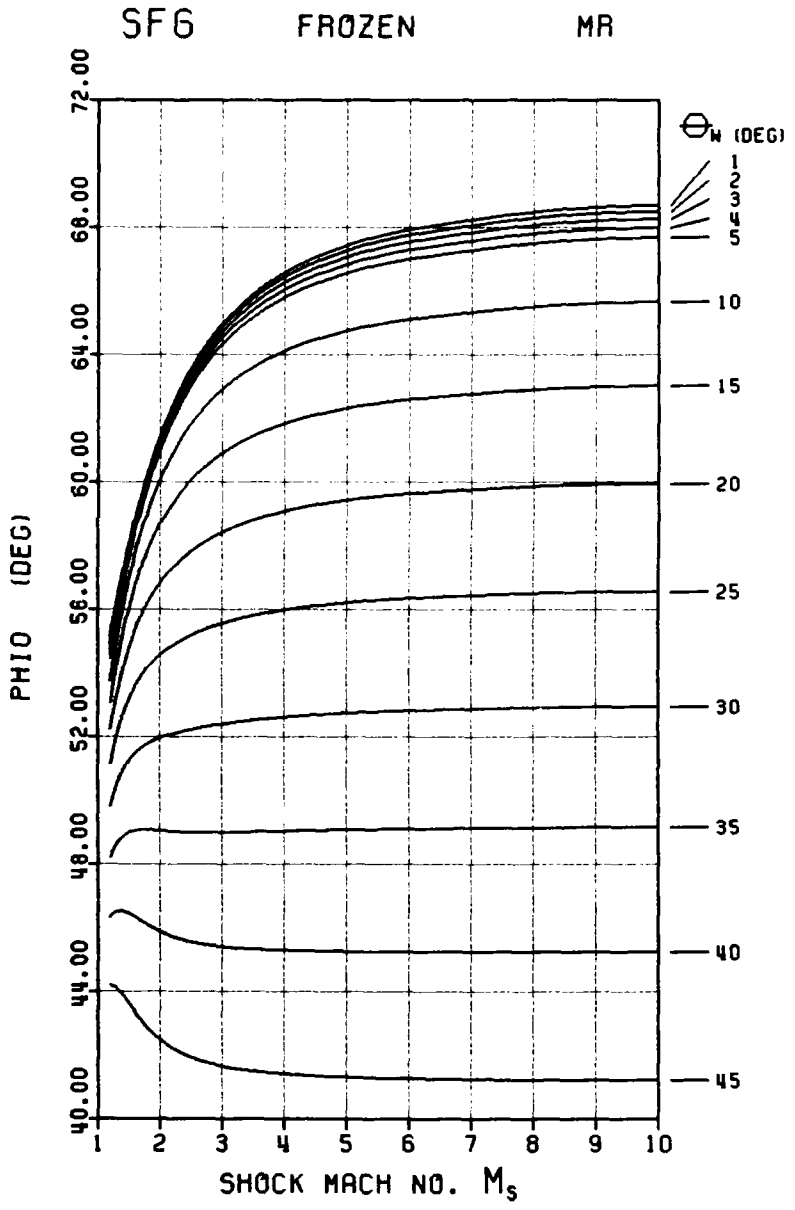

SF6 FROZEN MR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
1
0.70
0.90
1.10
1.30
1.50
1.70
1.90
2.10
2.30
1
2
3
4
5
6
7
8
9
10

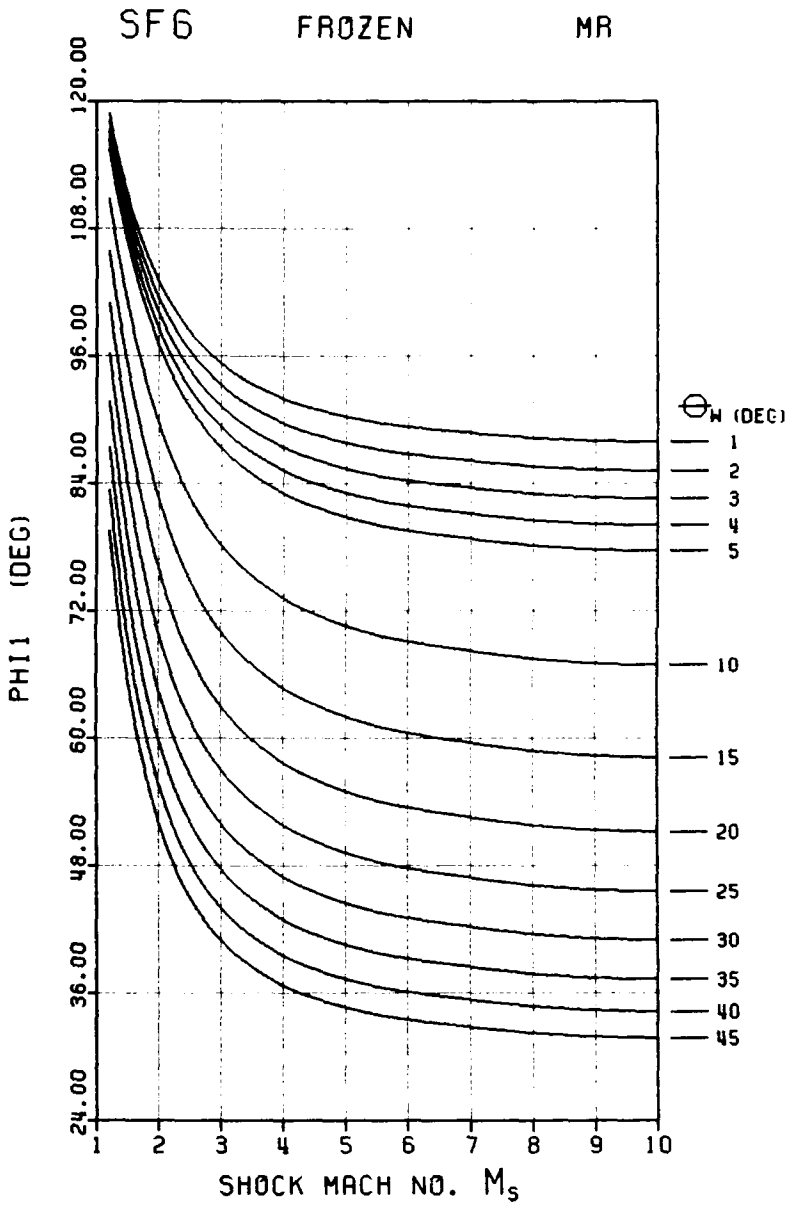

SF6 FROZEN MR
MACH2 RELATIVE TO KINK
SHOCK MACH NO. M_S
Θ_W (DEG)
20
15
10
5
1
45
40
35
30
25

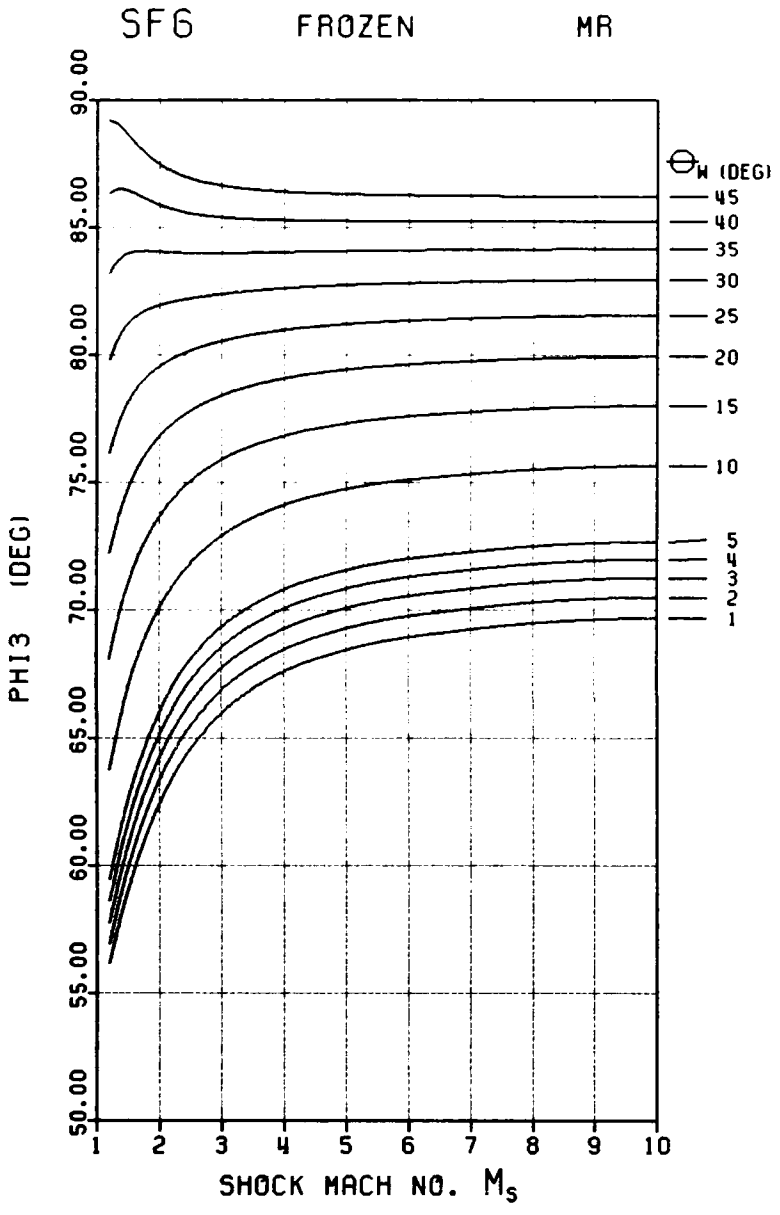

SF6 FROZEN MR
MACH3
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

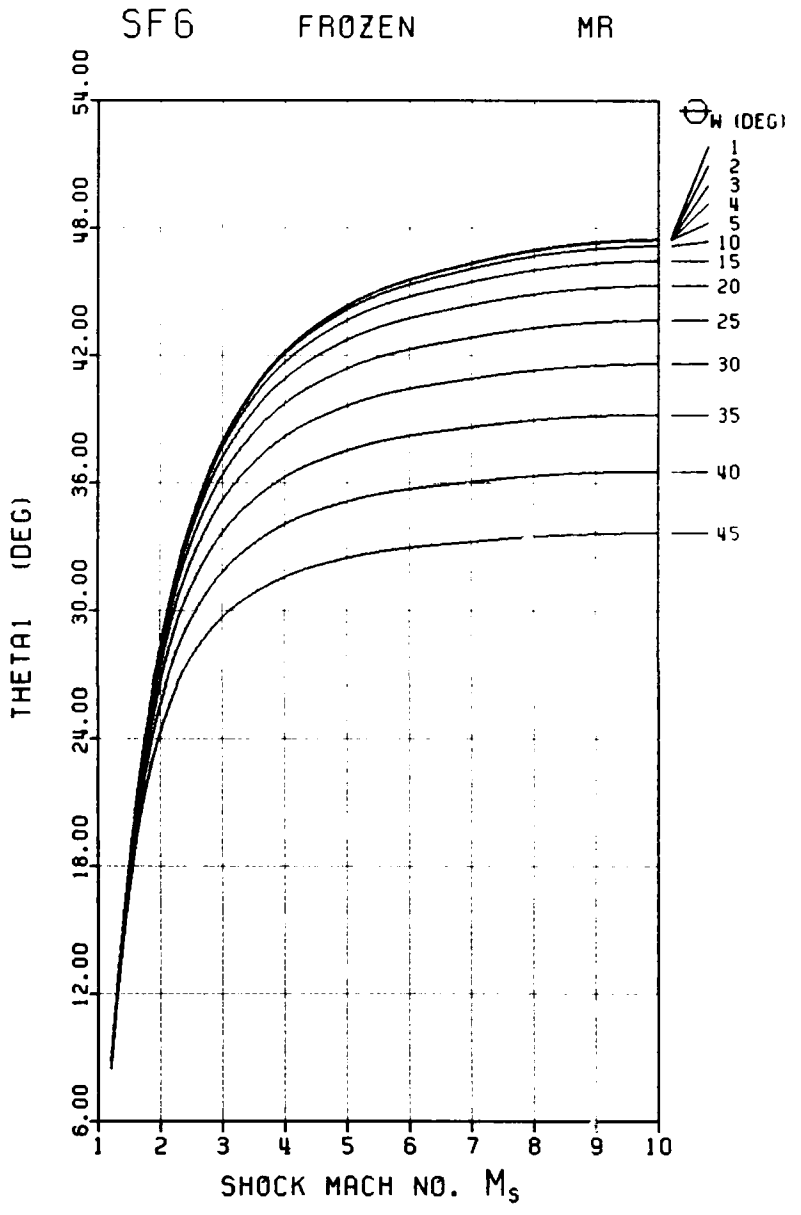

SF6 FROZEN MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A2 (M/SEC)
720.00
640.00
560.00
480.00
400.00
320.00
240.00
160.00
80.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

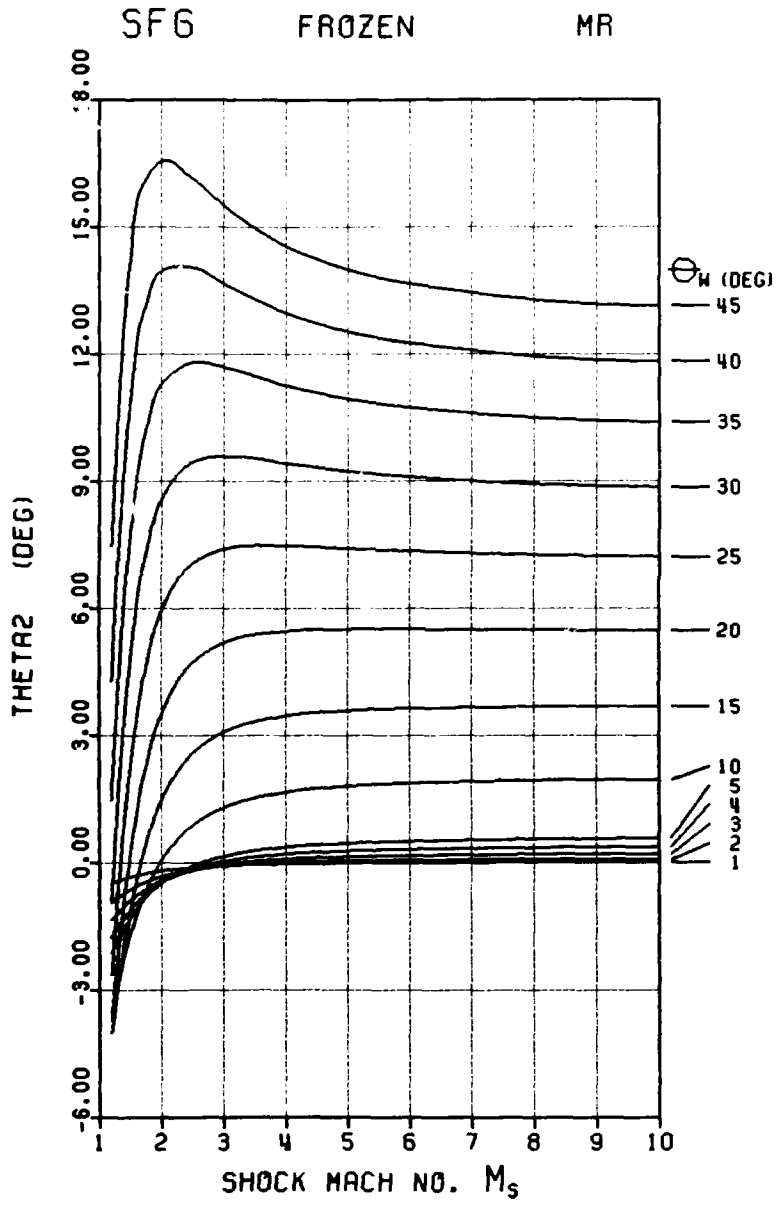

SF6 FROZEN MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A3 (M/SEC)
950
850
750
650
550
450
350
250
150
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

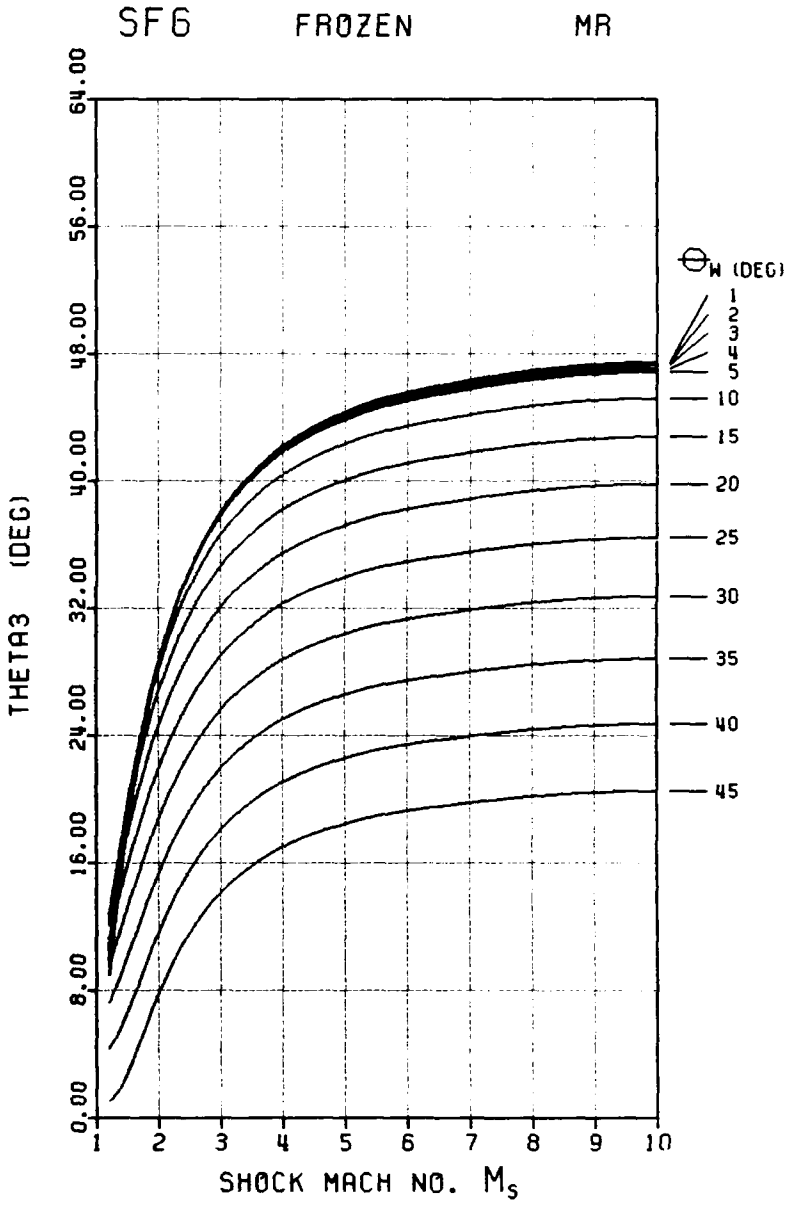

SF6 FROZEN MR
PHI0 (DEG)
72.00
68.00
64.00
60.00
56.00
52.00
48.00
44.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

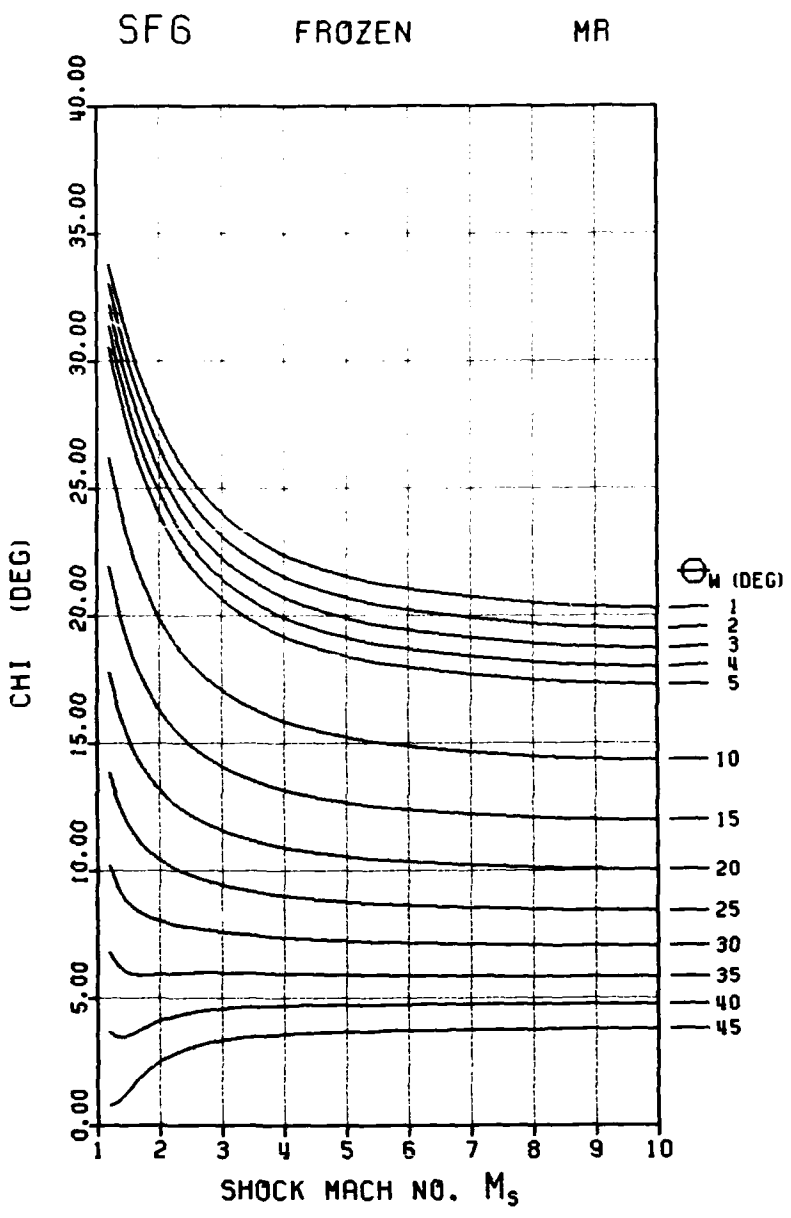

SF6 FROZEN MR
PHI1 (DEG)
120.00
108.00
96.00
84.00
72.00
60.00
48.00
36.00
24.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

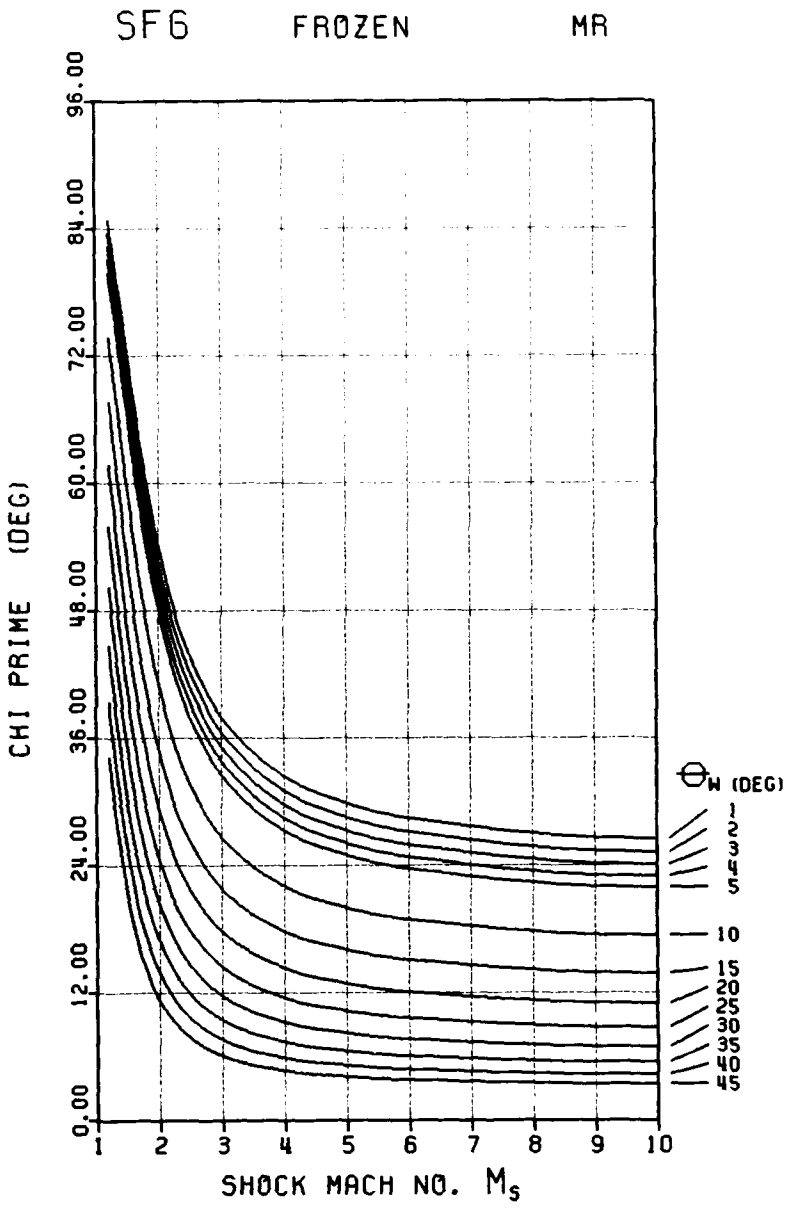

SF6 FROZEN MR
PHI3 (DEG)
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

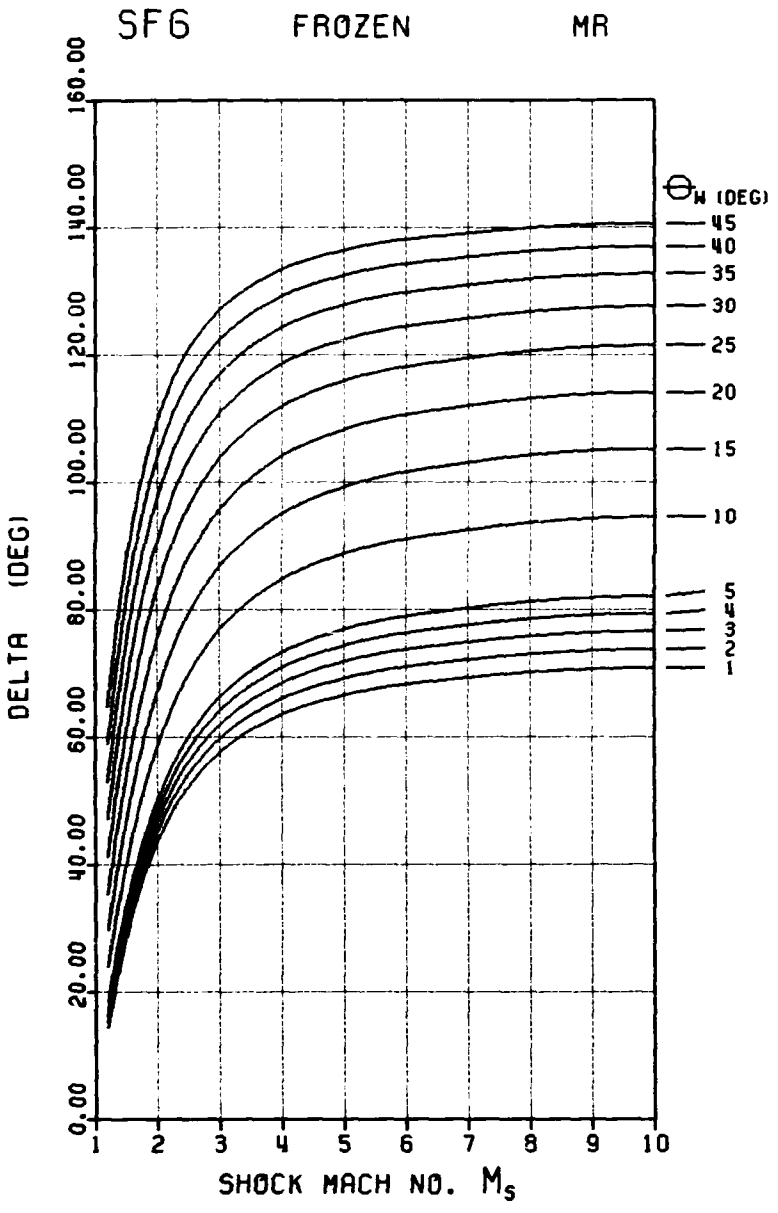

SF6 FROZEN MR
THETA1 (DEG)
54.00
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

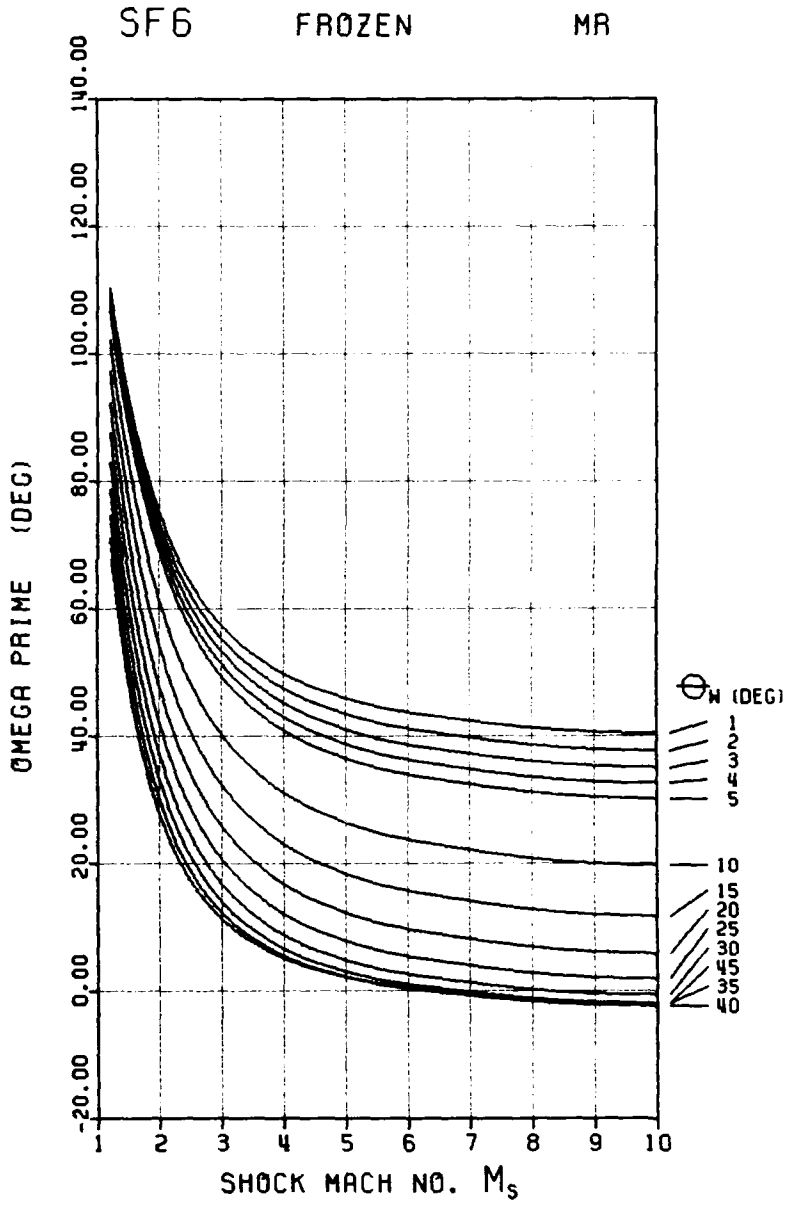

SF6 FROZEN MR
THETA2 (DEG)
18.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

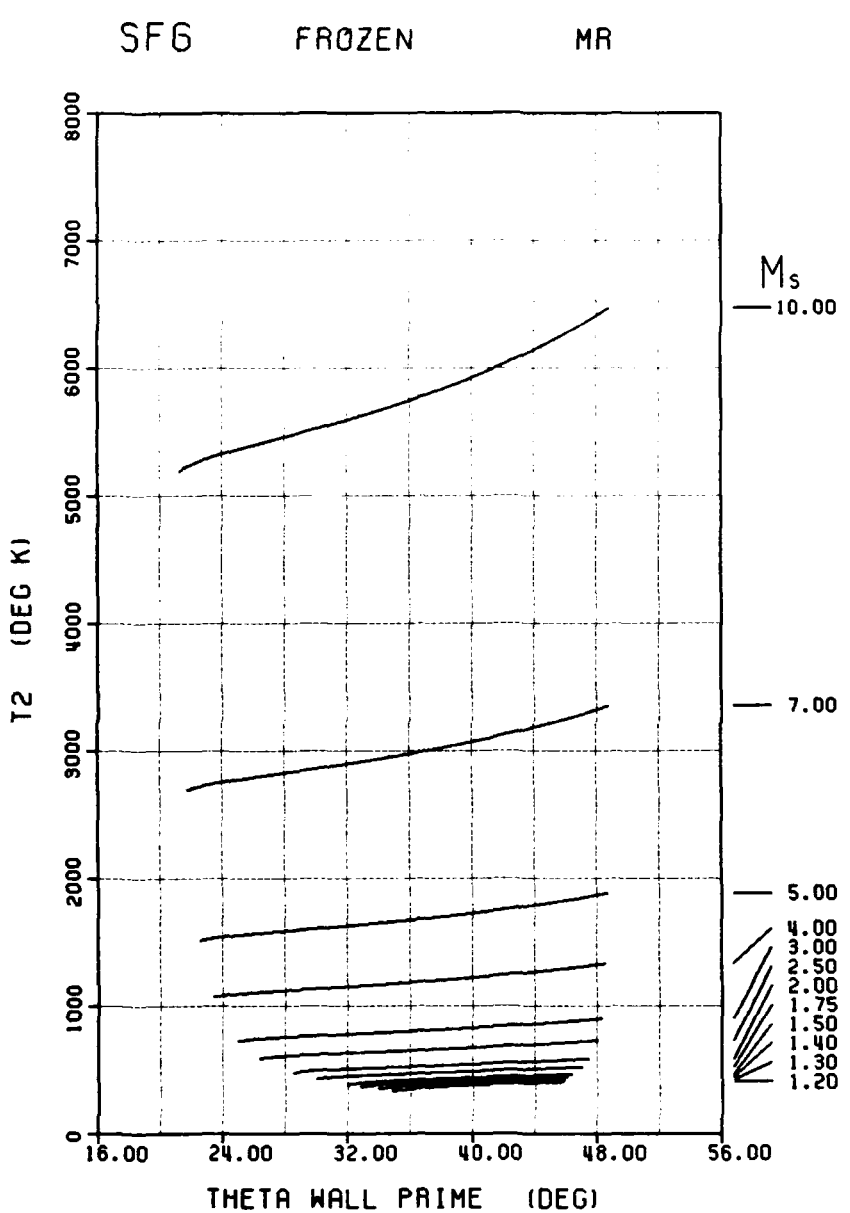

SF6 FROZEN MR
THETA3 (DEG)
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

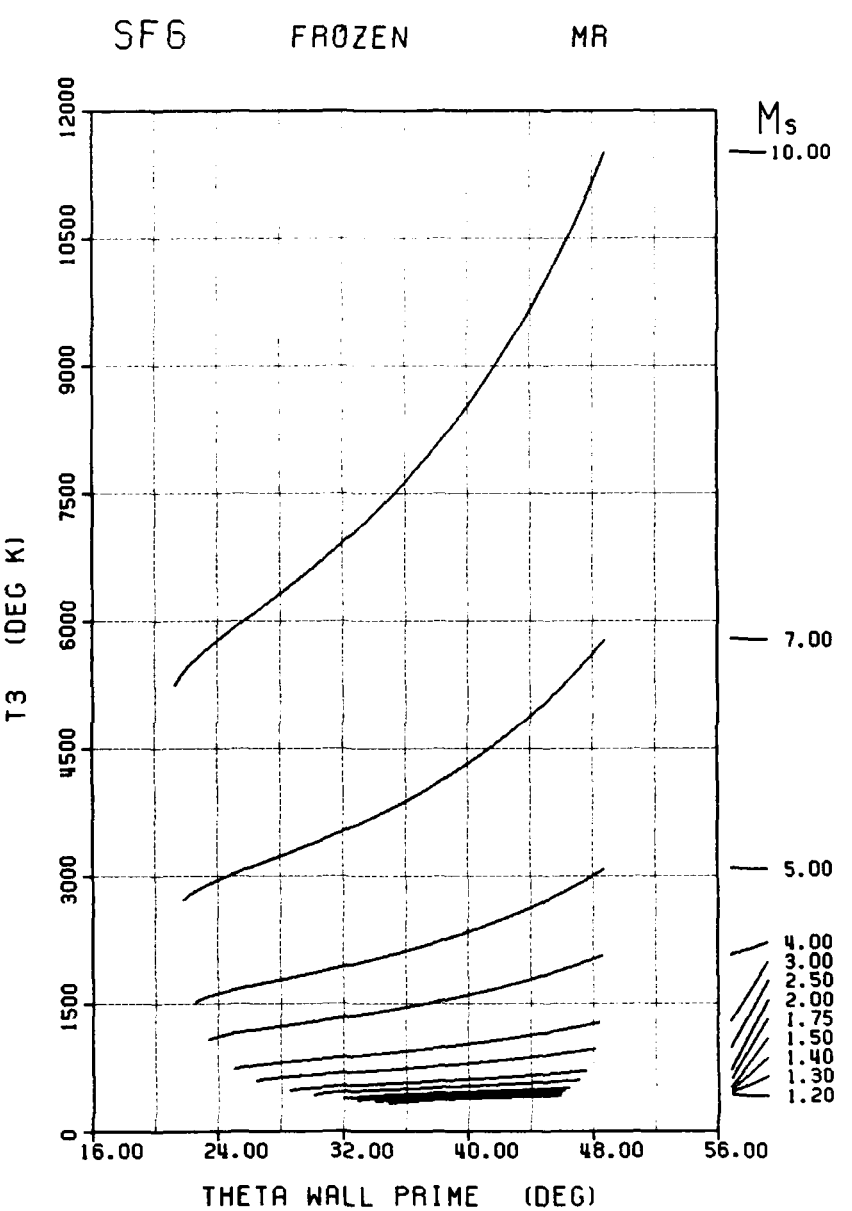

SF6 FROZEN MR
CHI (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

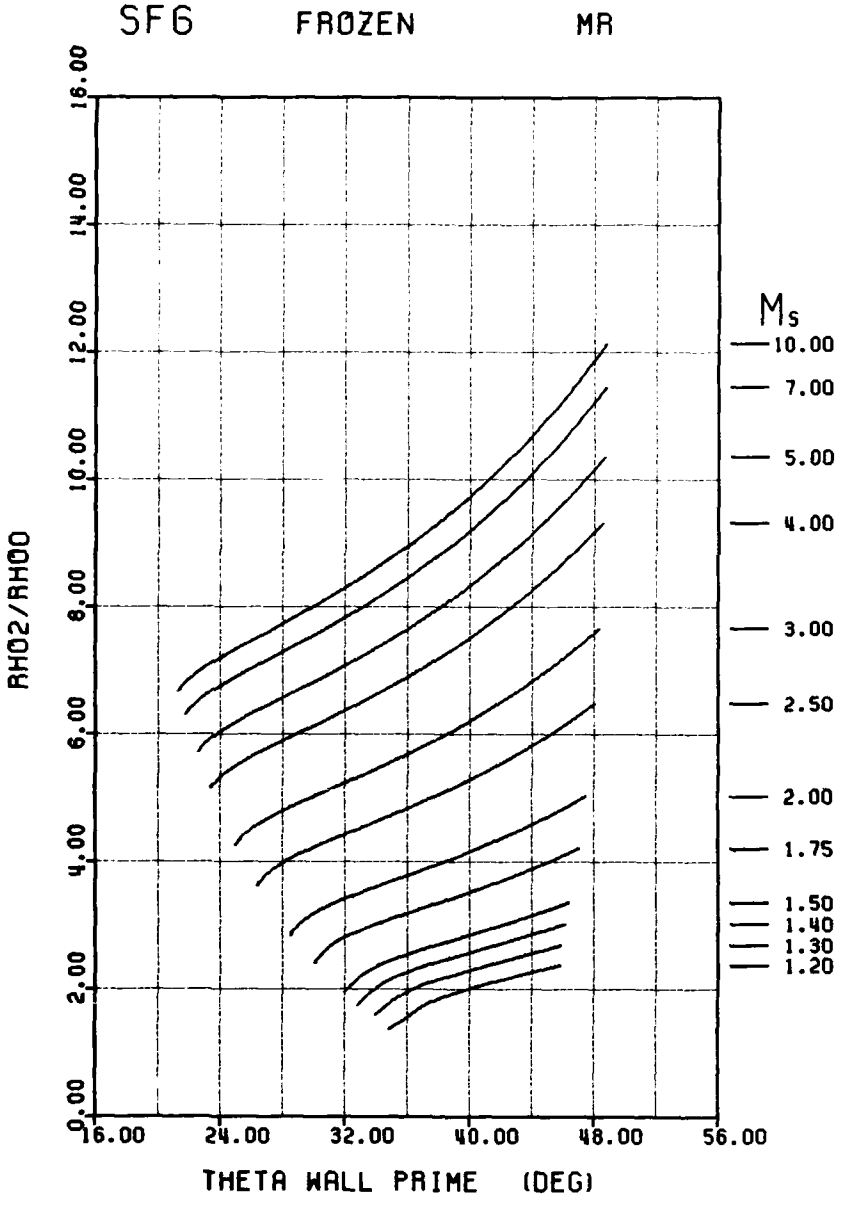

SF6 FROZEN MR
CHI PRIME (DEG)
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

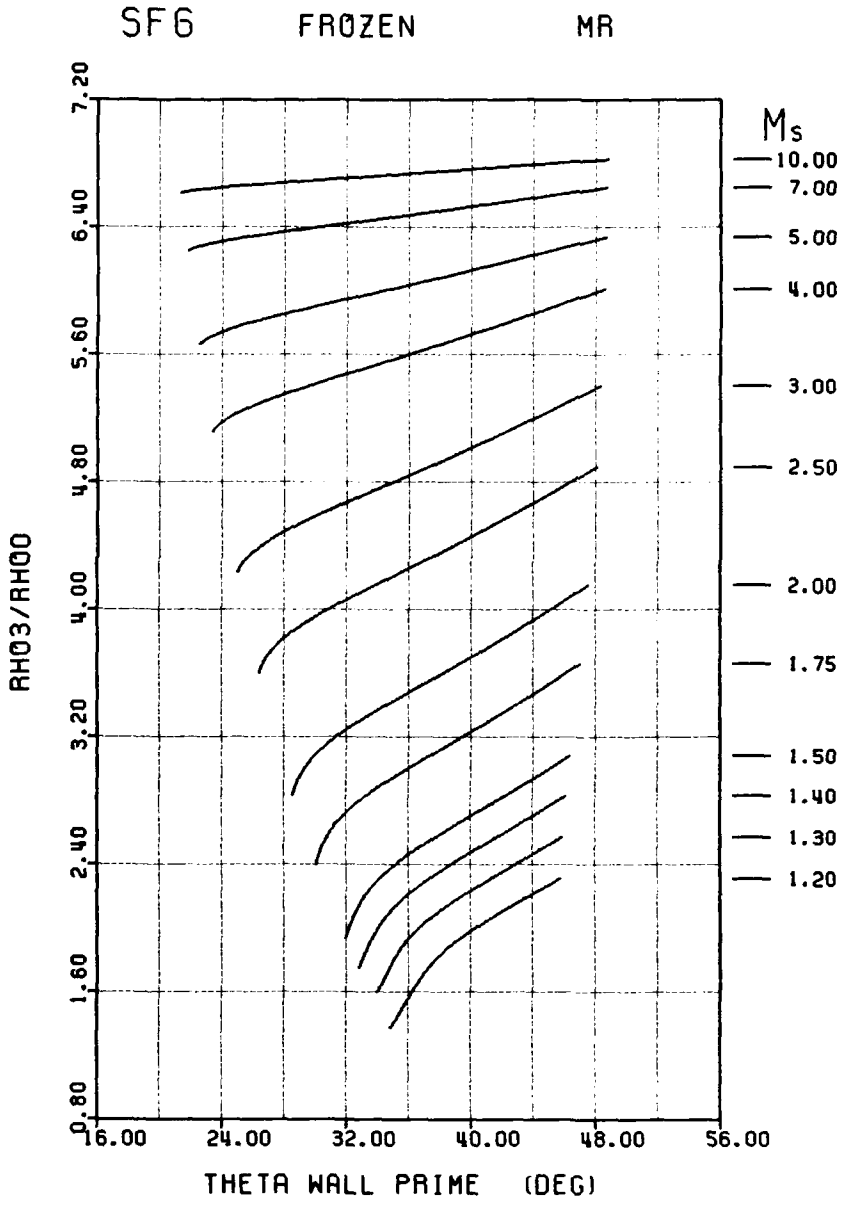

SF6 FROZEN MR
DELTA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
1
2
3
4
5
6
7
8
9
10

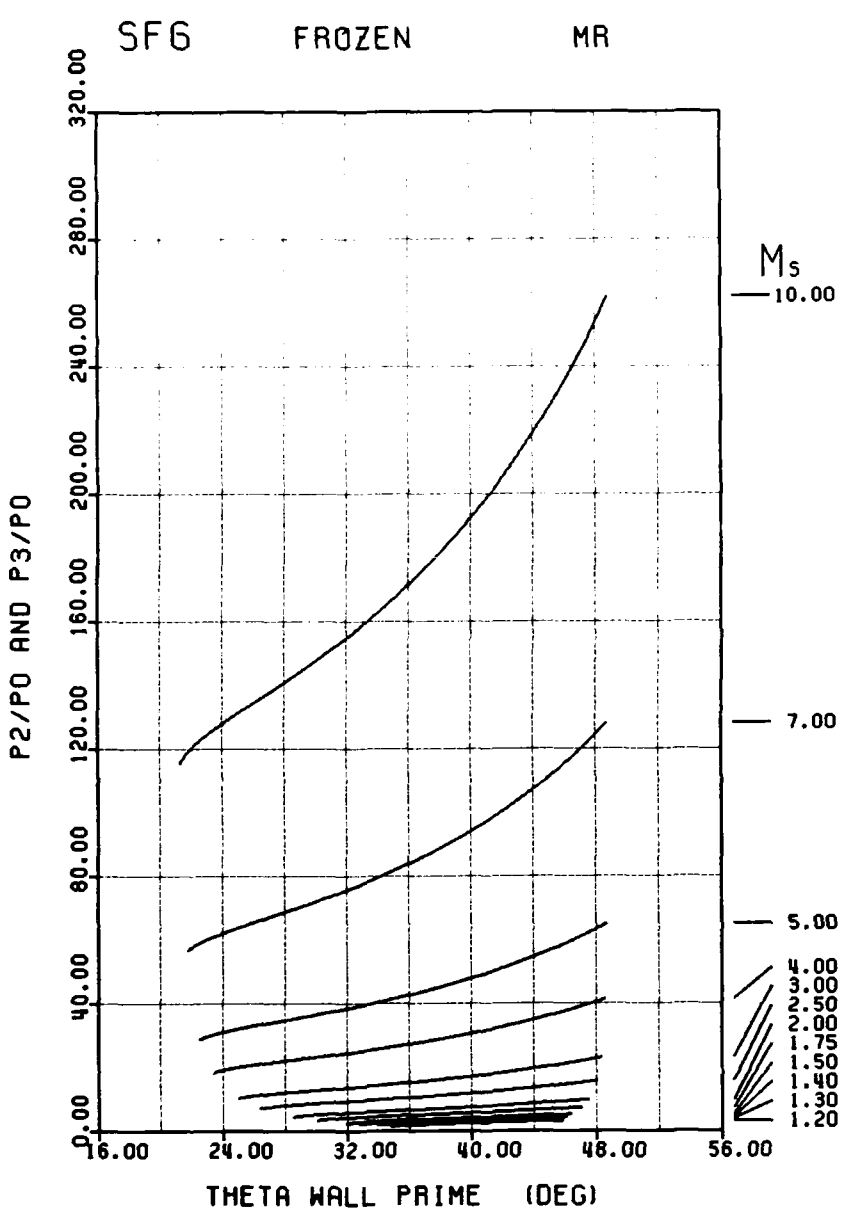

SF6 FROZEN MR
OMEGA PRIME (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
45
35
40
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
1
2
3
4
5
6
7
8
9
10

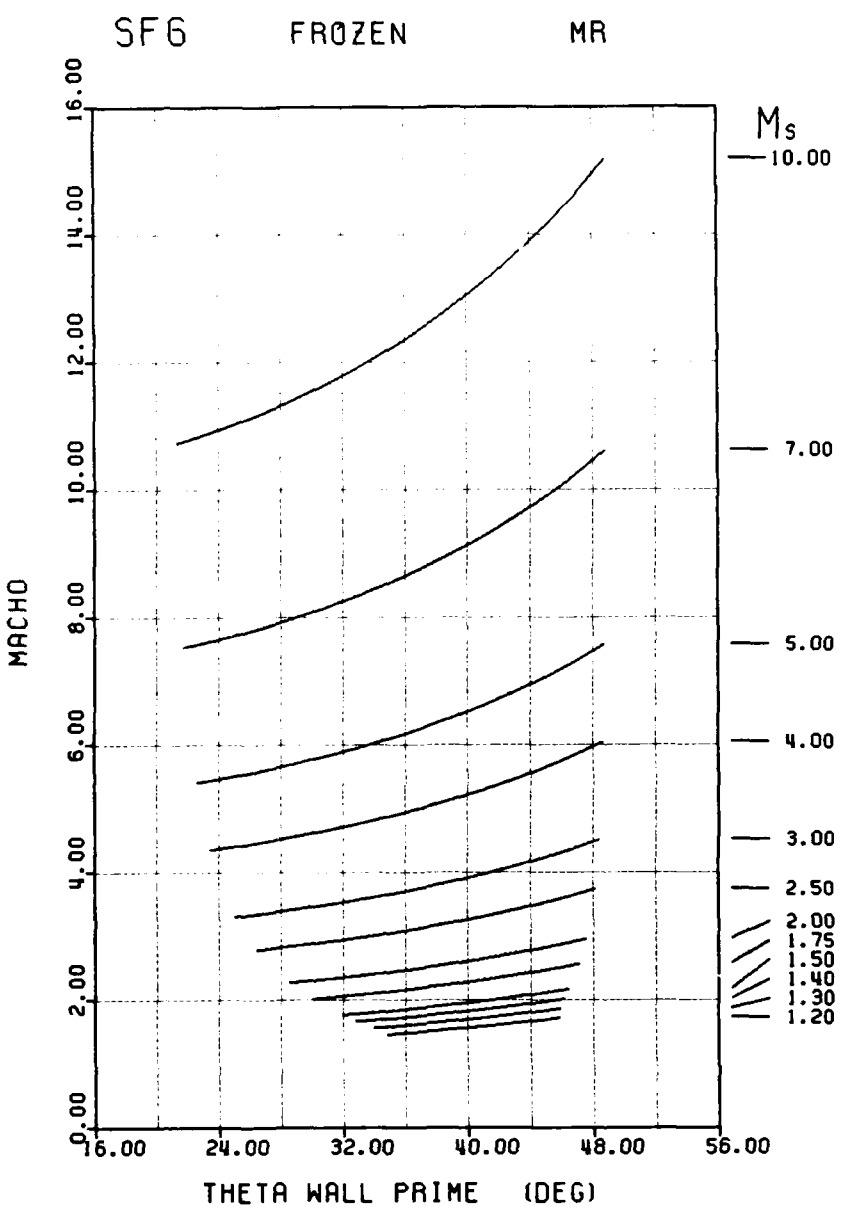

SF6 FROZEN MR
T2 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
1000
2000
3000
4000
5000
6000
7000
8000
16.00
24.00
32.00
40.00
48.00
56.00

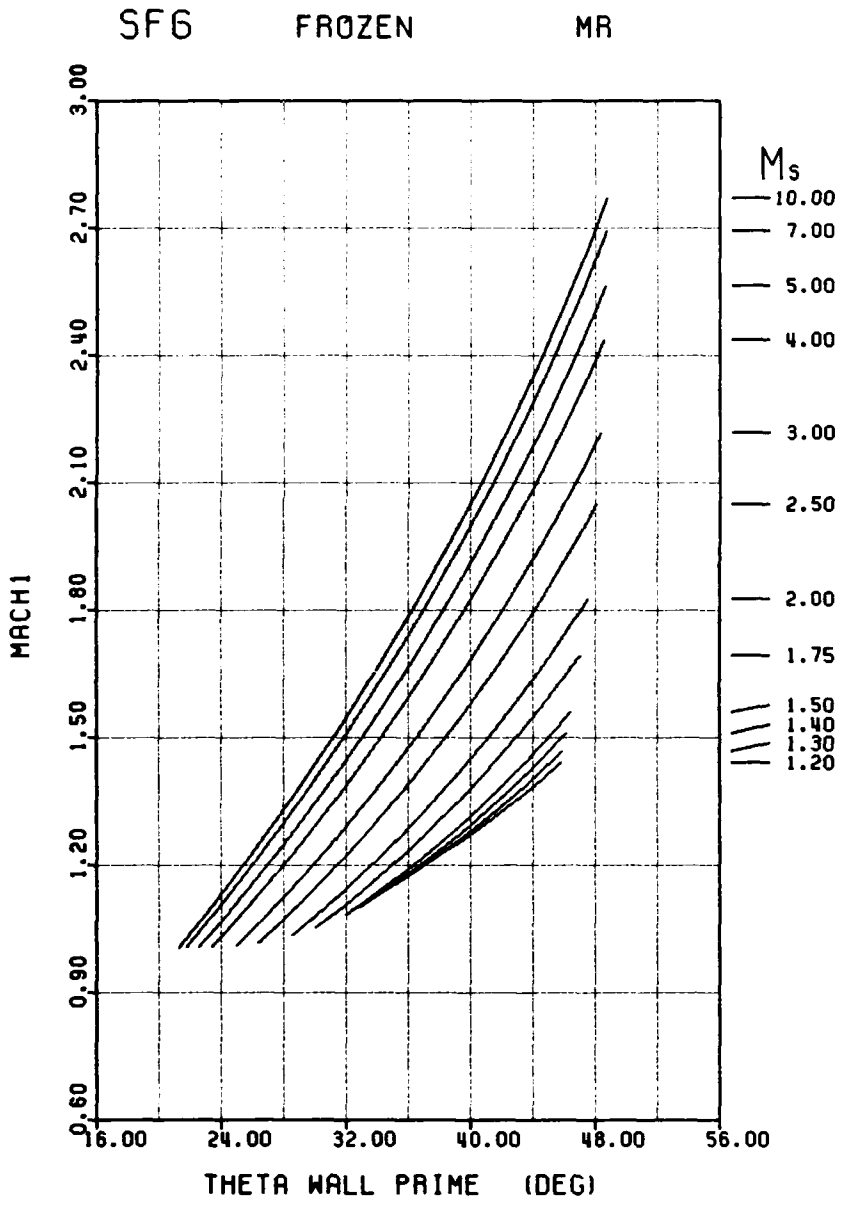

SF6 FROZEN MR
T3 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
1500
3000
4500
6000
7500
9000
10500
12000
16.00
24.00
32.00
40.00
48.00
56.00

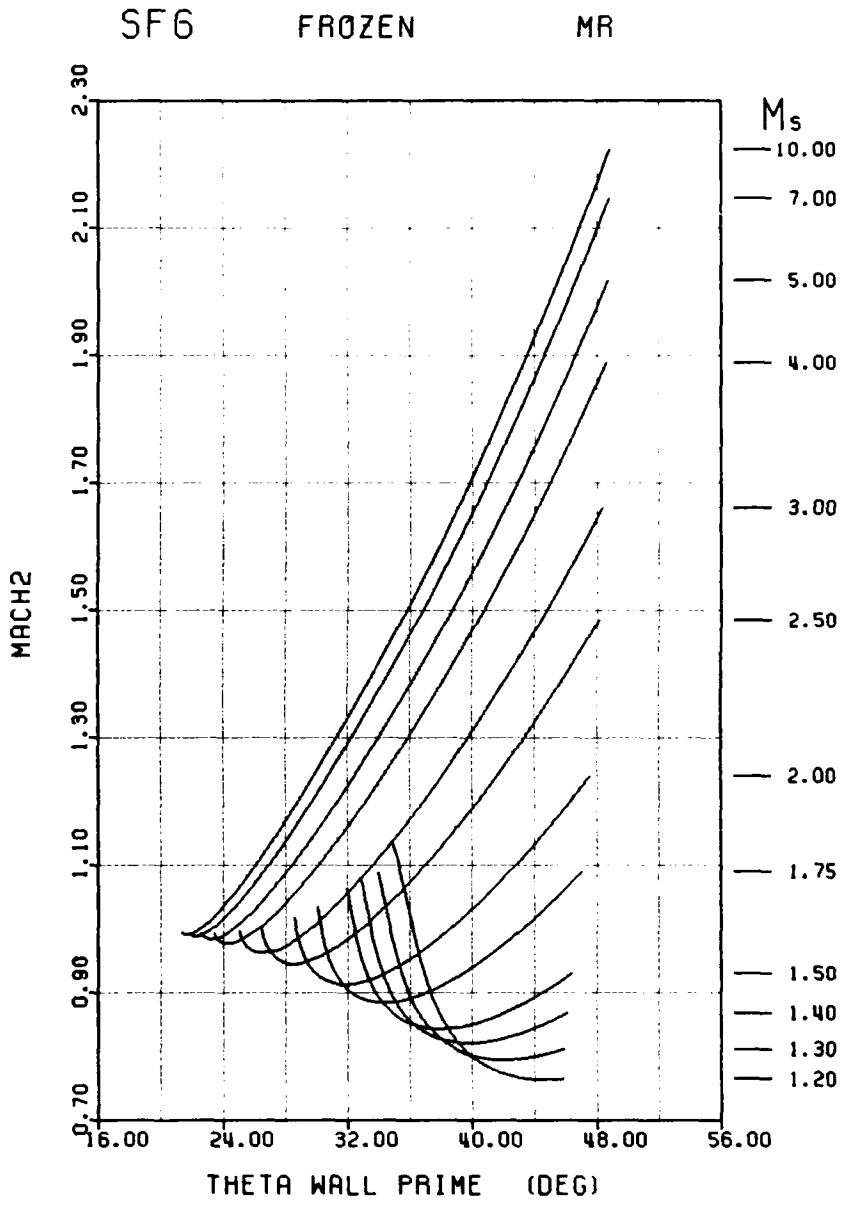

SF6 FROZEN MR
RH02/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

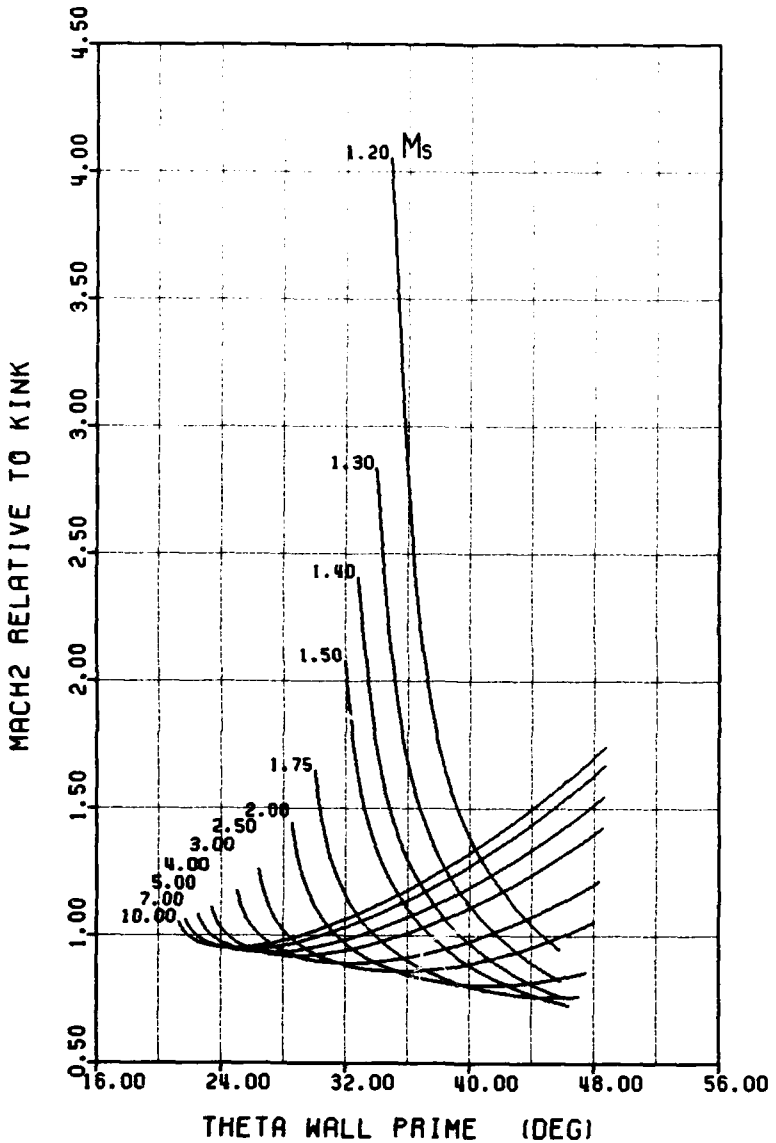

SF6 FROZEN MR
RH03/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

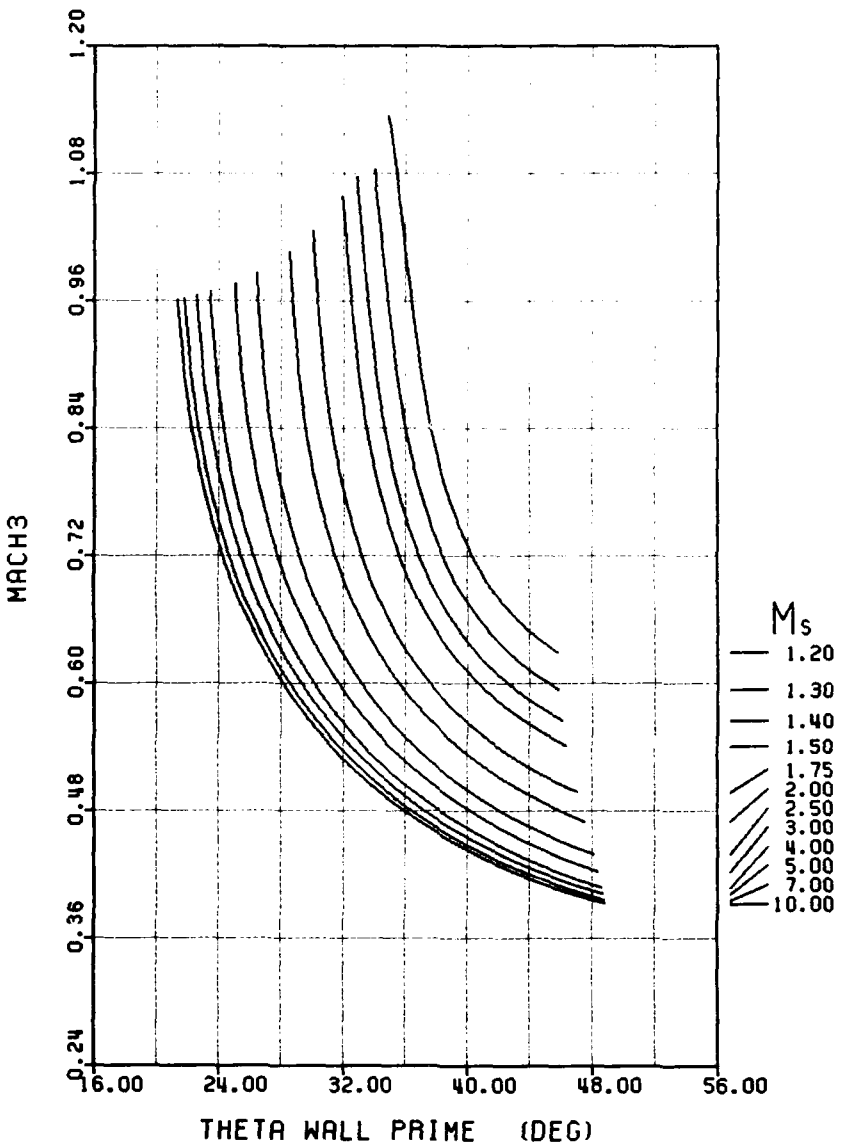

SF6 FROZEN MR
P2/P0 AND P3/P0
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

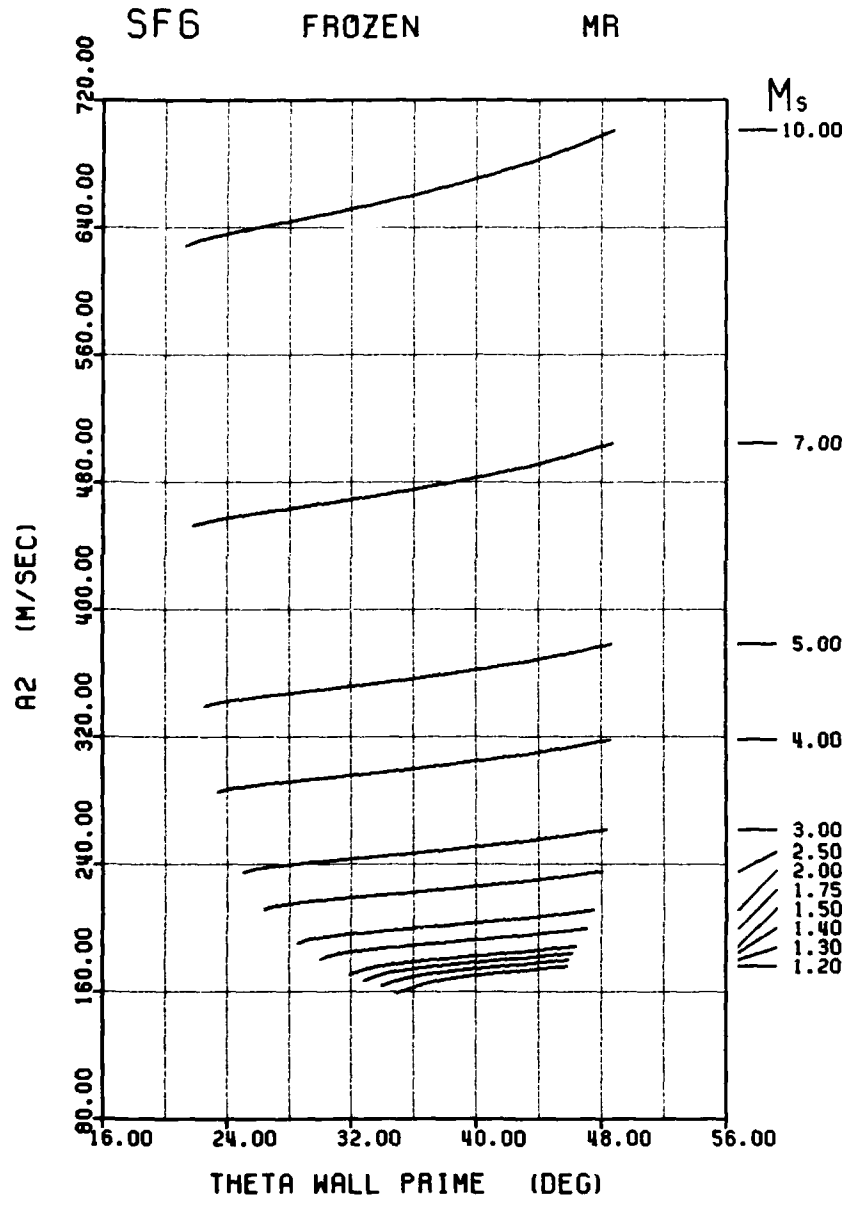

SF6 FROZEN MR
MACH0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

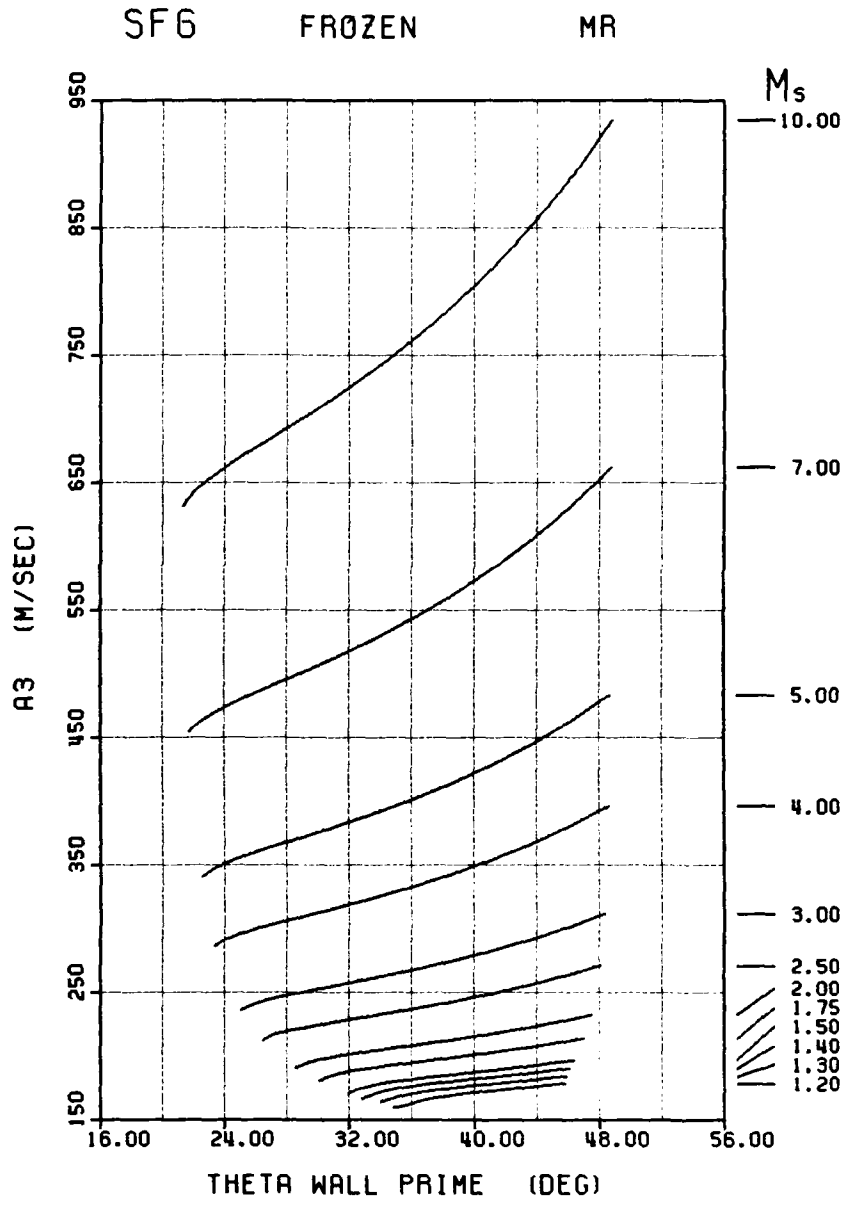

SF6 FROZEN MR
MACH1
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
16.00
24.00
32.00
40.00
48.00
56.00

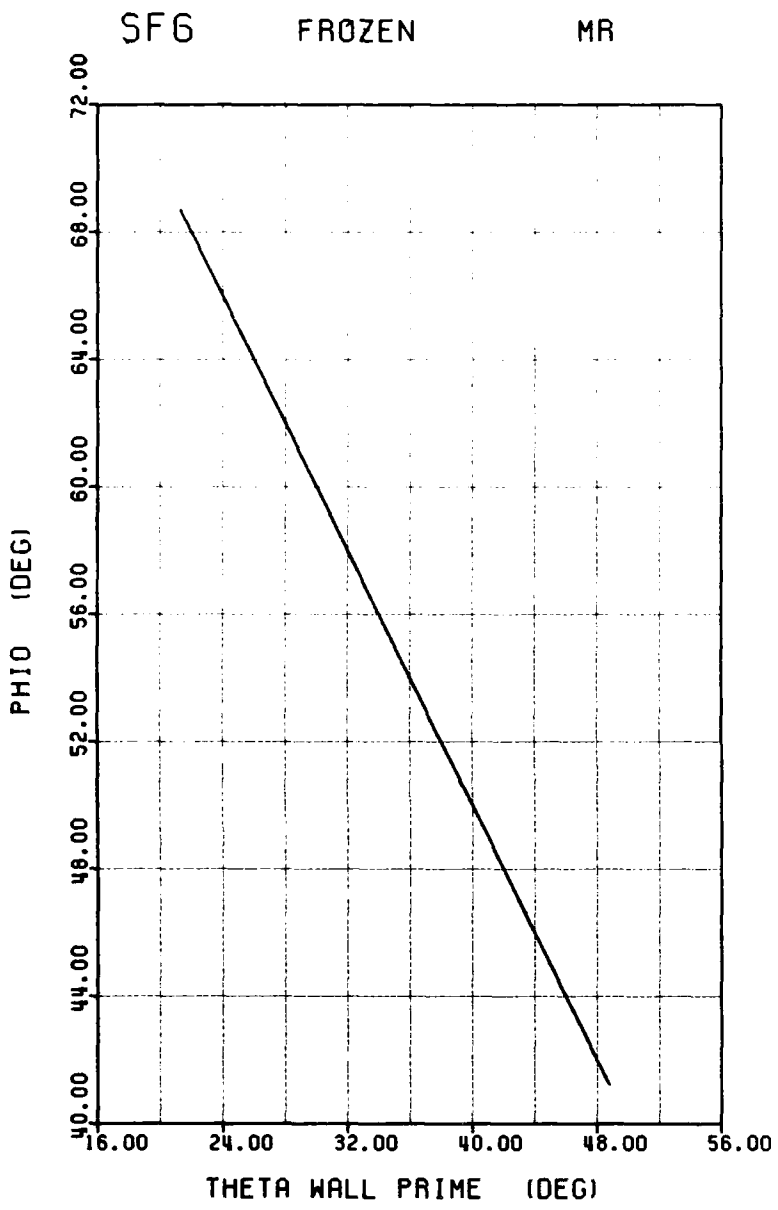

SF6 FROZEN MR
MACH2
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.70
0.90
1.10
1.30
1.50
1.70
1.90
2.10
2.30
16.00
24.00
32.00
40.00
48.00
56.00

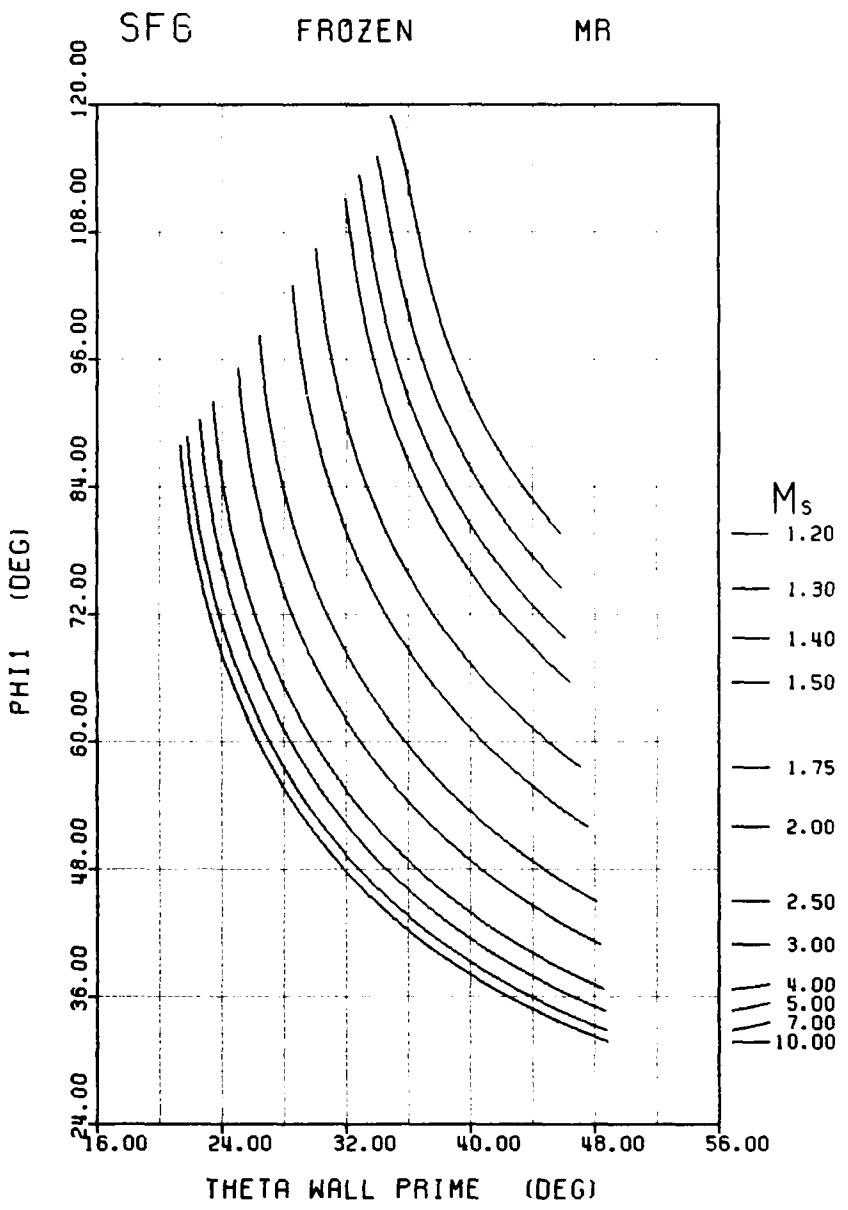

SF6 FROZEN MR
MACH2 RELATIVE TO KINK
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
16.00
24.00
32.00
40.00
48.00
56.00

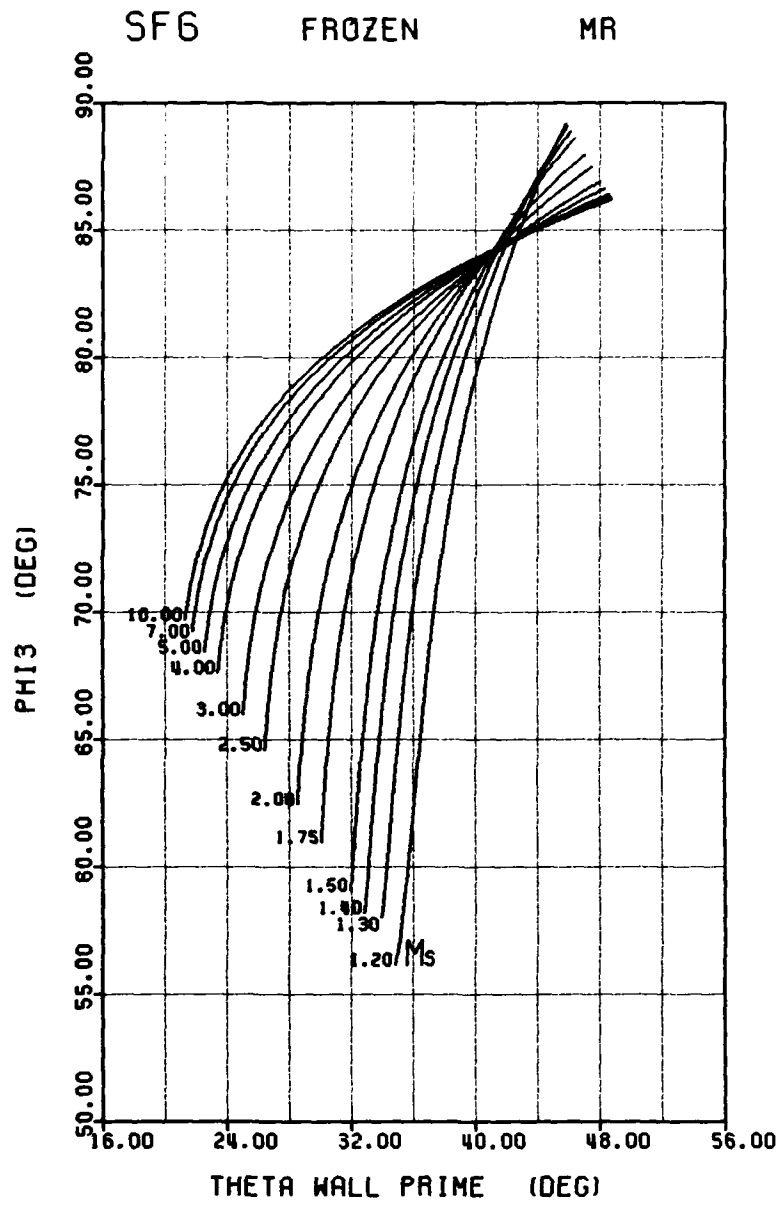

SF6 FROZEN MR
MACH3
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.24
0.36
0.48
0.60
0.72
0.84
0.96
1.08
1.20
16.00
24.00
32.00
40.00
48.00
56.00

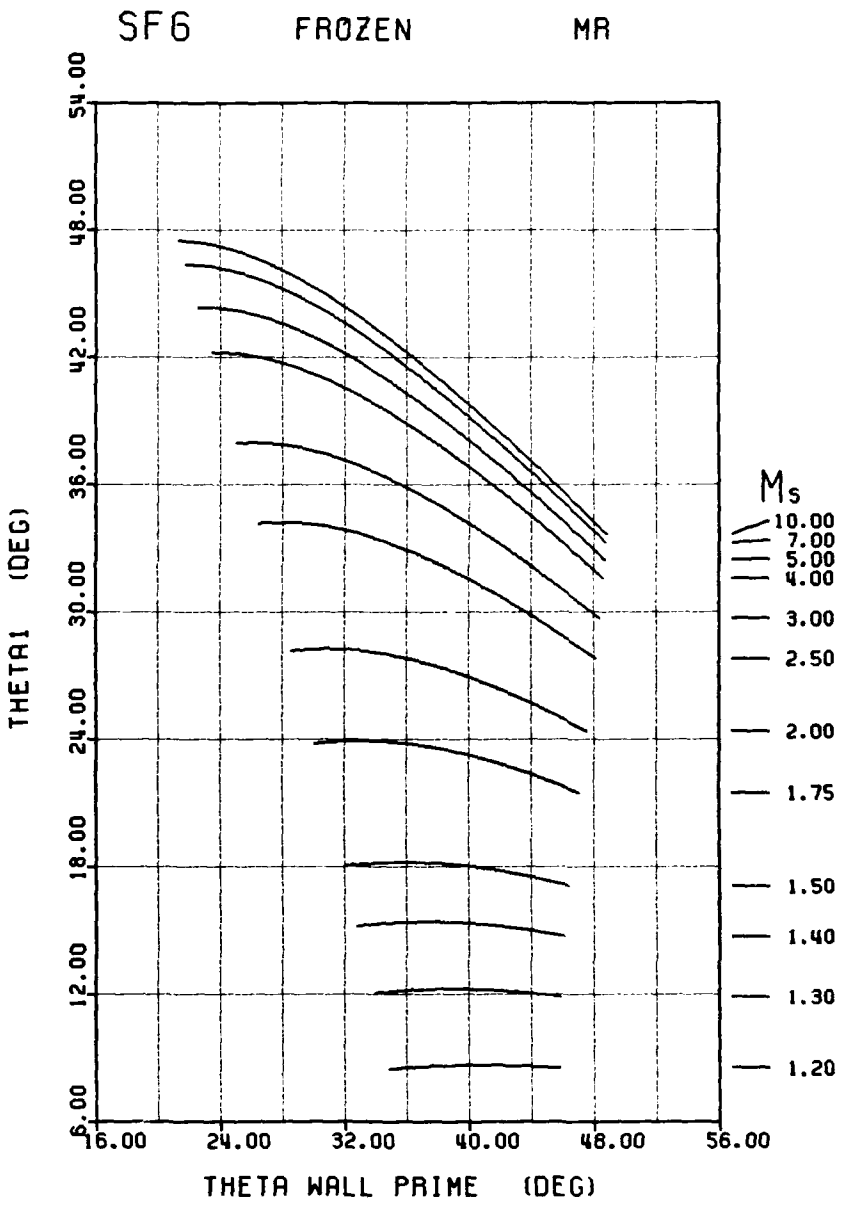

SF6 FROZEN MR
A2 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
720.00
640.00
560.00
480.00
400.00
320.00
240.00
160.00
80.00
16.00
24.00
32.00
40.00
48.00
56.00

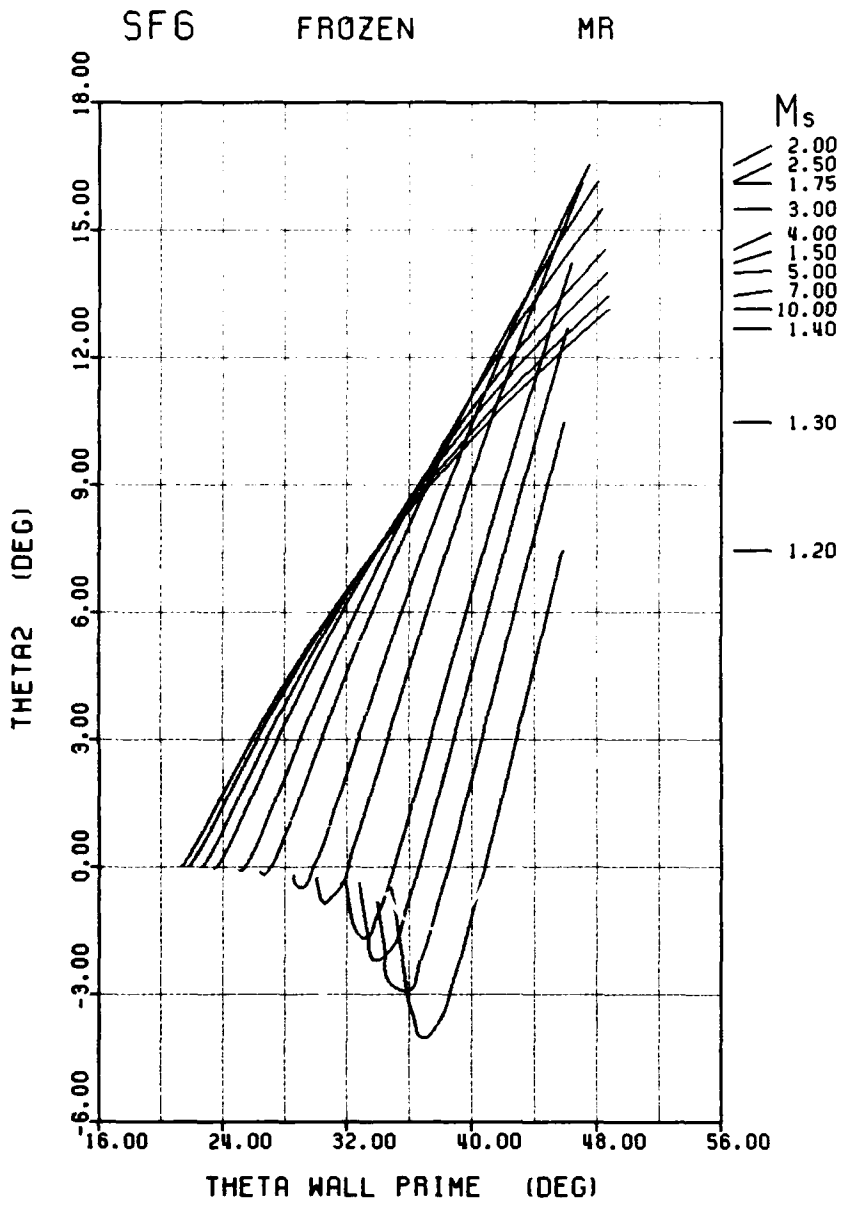

SF6 FROZEN MR
A3 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
950
850
750
650
550
450
350
250
150
16.00
24.00
32.00
40.00
48.00
56.00

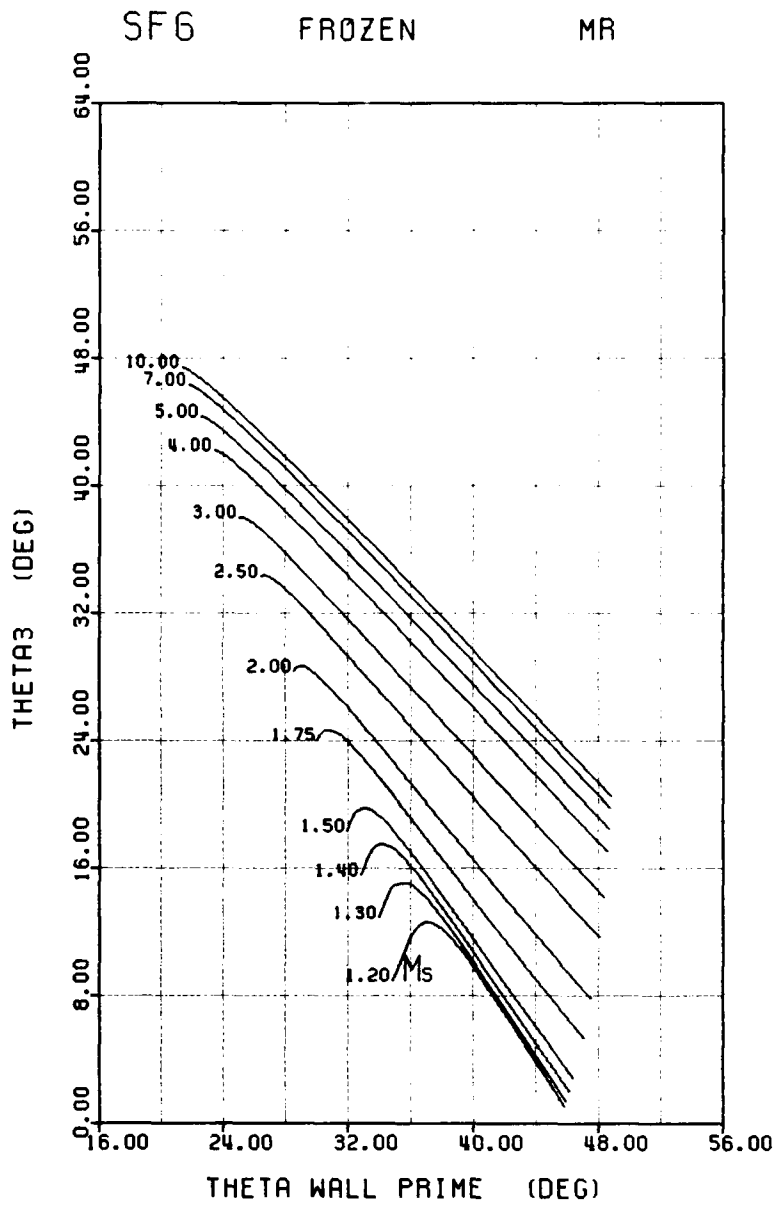

SF6 FROZEN MR
PHI0 (DEG)
72.00
68.00
64.00
60.00
56.00
52.00
48.00
44.00
40.00
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)

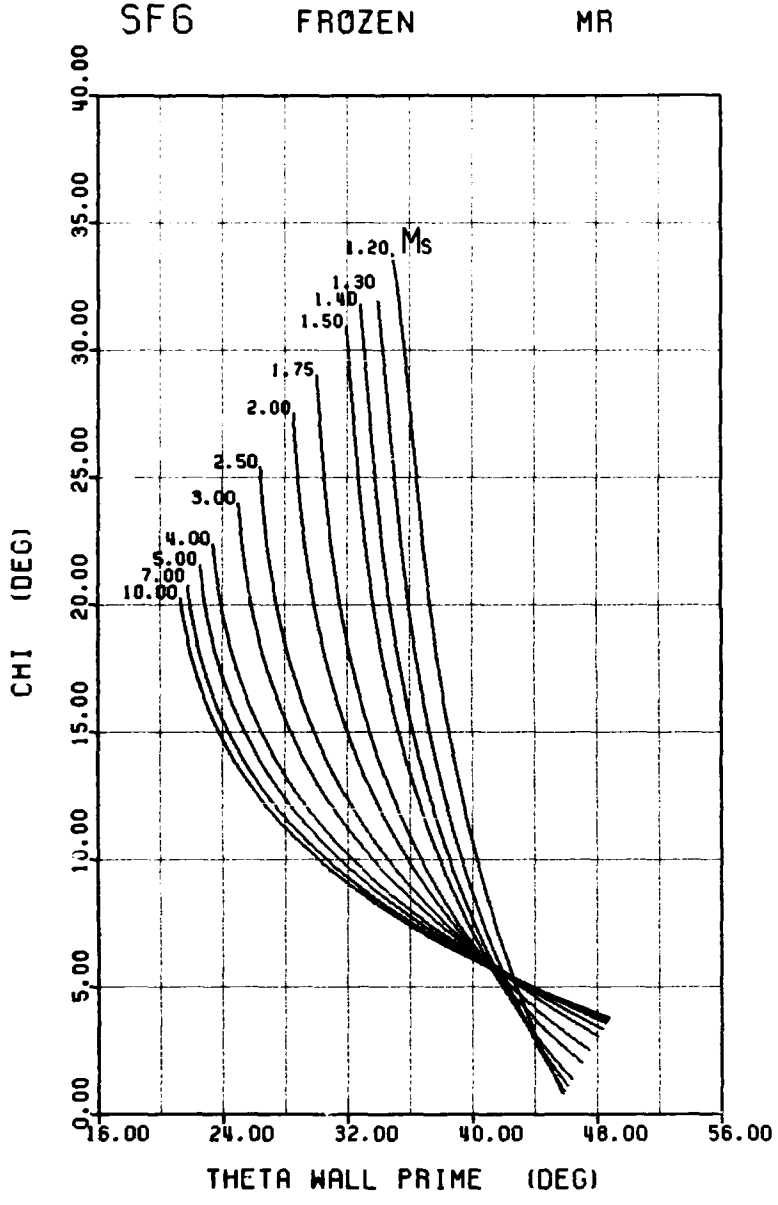

SF6 FROZEN MR
PHI1 (DEG)
120.00
108.00
96.00
84.00
72.00
60.00
48.00
36.00
24.00
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

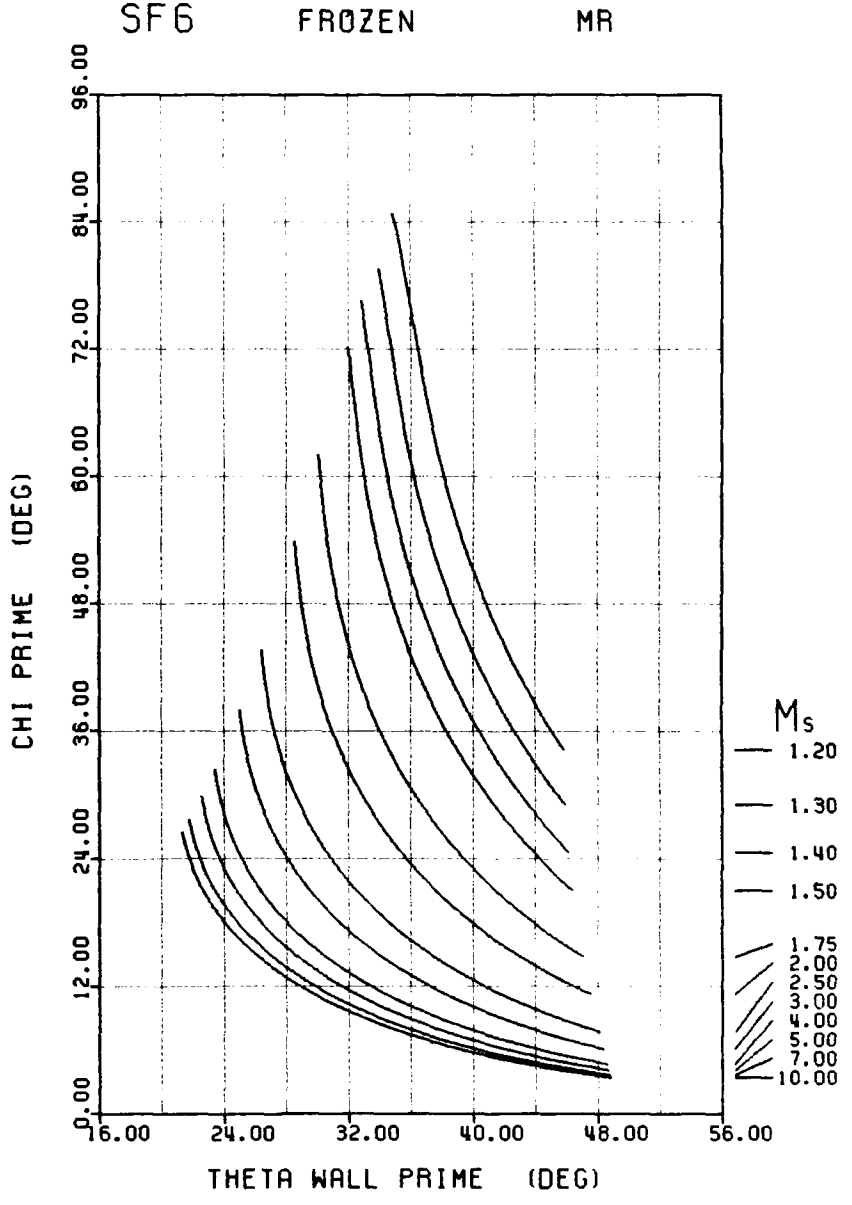

SF6 FROZEN MR
PHI3 (DEG)
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)

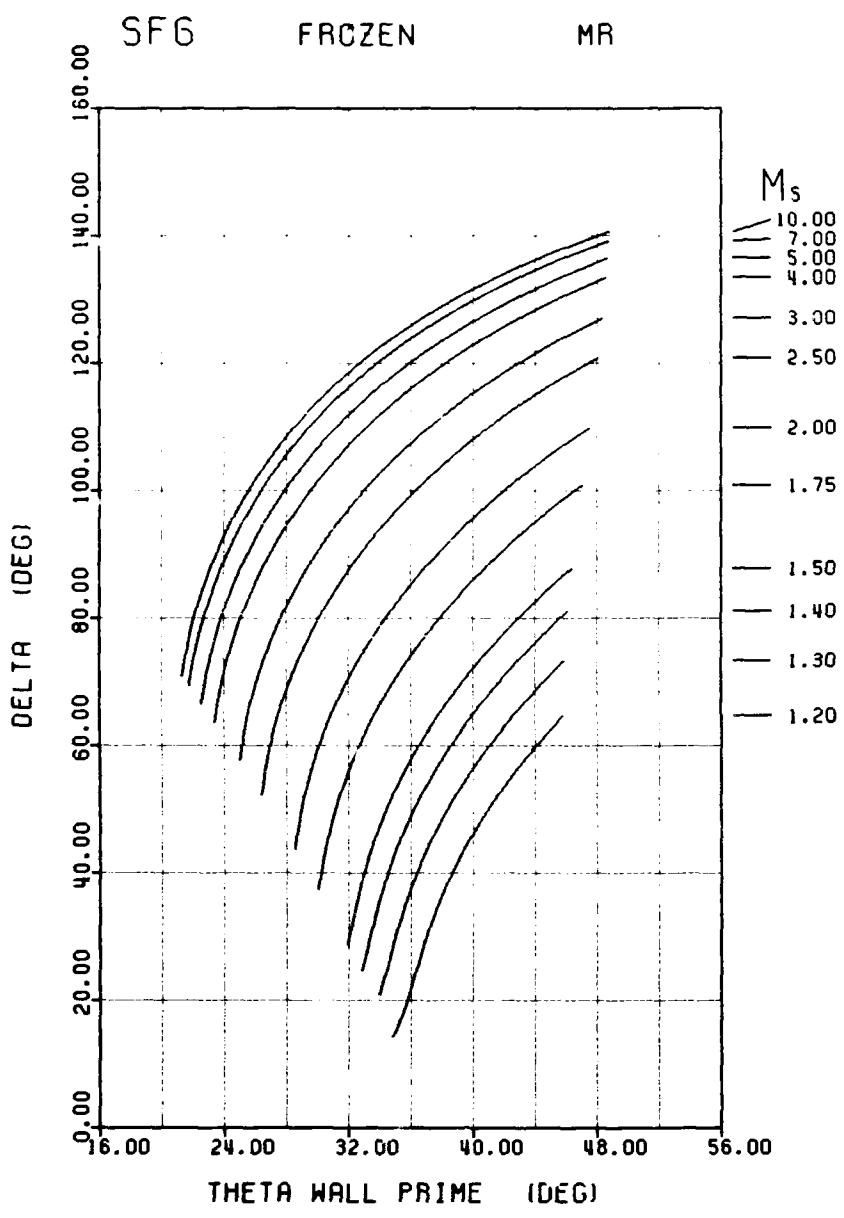

SF6 FROZEN MR
THETA1 (DEG)
54.00
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
16.00
24.00
32.00
40.00
48.00
56.00
THETA WALL PRIME (DEG)

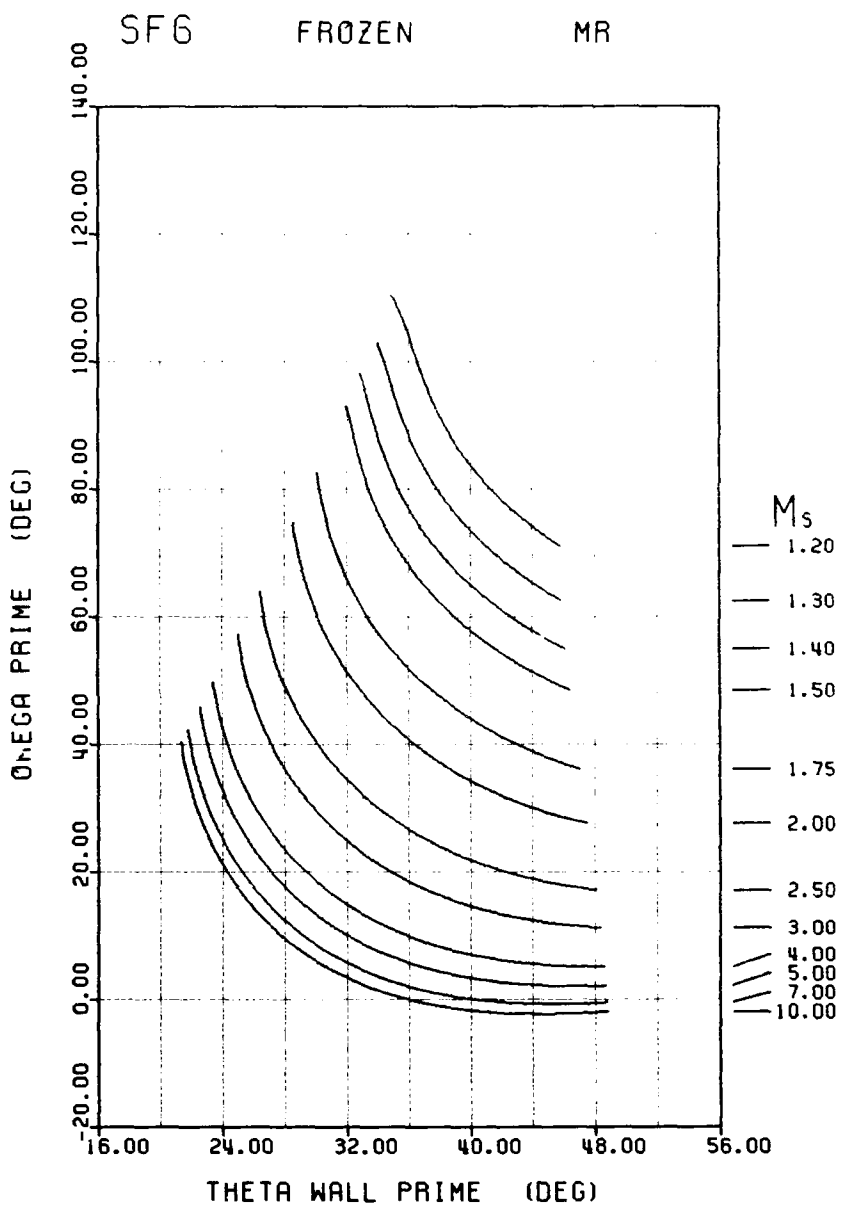

SF6 FROZEN MR
THETA2 (DEG)
THETA WALL PRIME (DEG)
Ms
2.00
2.50
1.75
3.00
4.00
1.50
5.00
7.00
10.00
1.40
1.30
1.20
18.00
15.00
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
16.00
24.00
32.00
40.00
48.00
56.00


SF6 FROZEN MR
THETA3 (DEG)
THETA WALL PRIME (DEG)
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
16.00
24.00
32.00
40.00
48.00
56.00


SF6 FROZEN MR
CHI (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
16.00
24.00
32.00
40.00
48.00
56.00

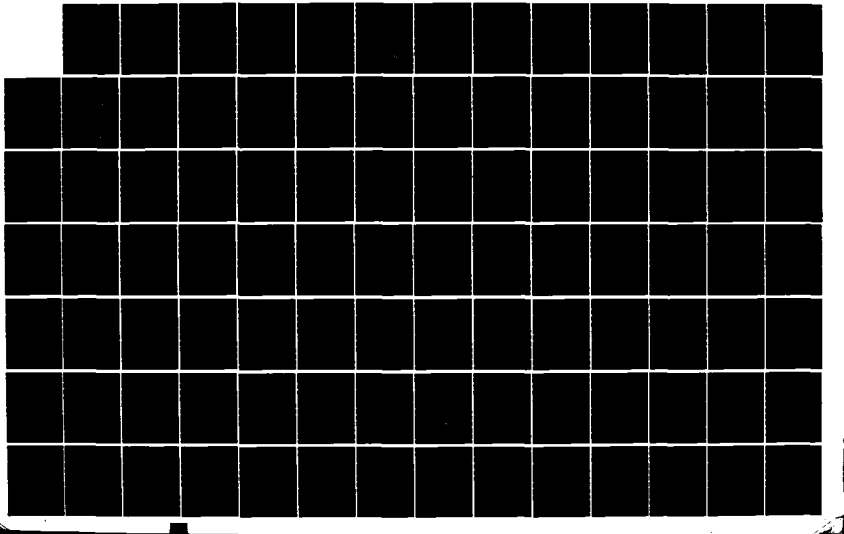

SF6 FROZEN MR
CHI PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
16.00
24.00
32.00
40.00
48.00
56.00

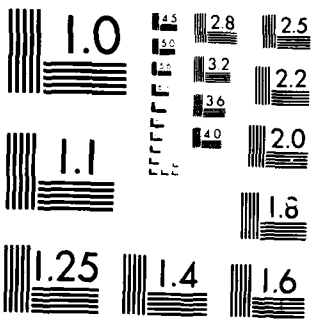

SF6 FROZEN MR
DELTA (DEG)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
16.00
24.00
32.00
40.00
48.00
56.00

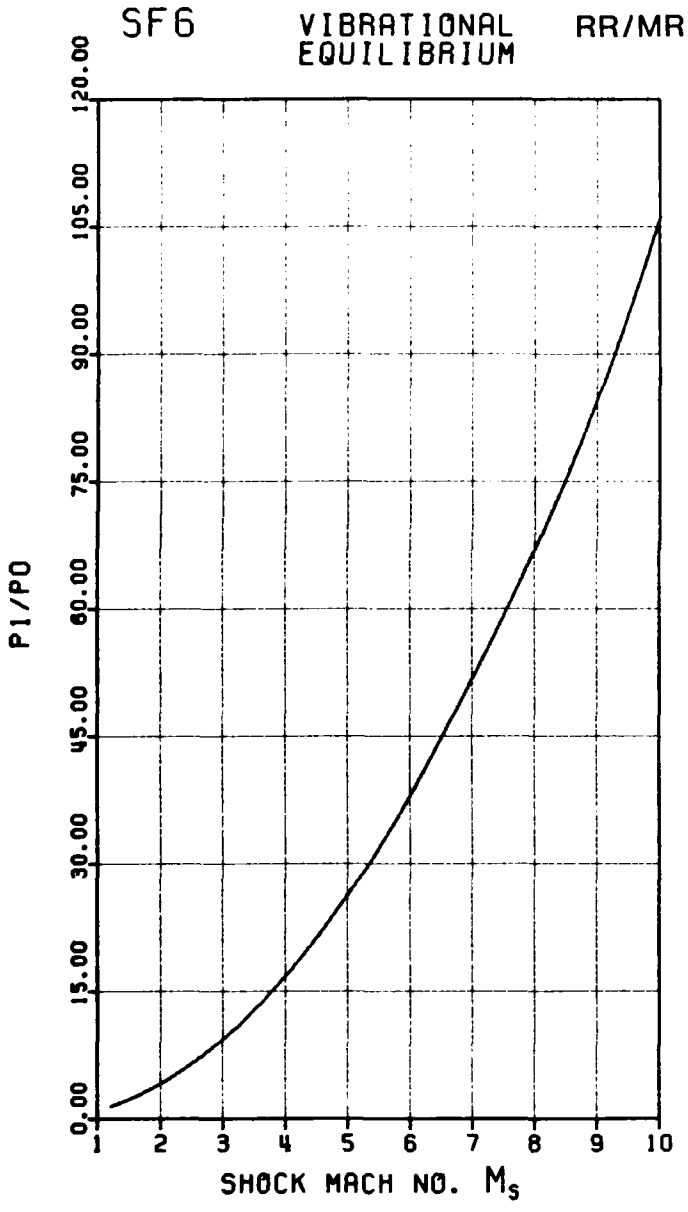

SF6 FROZEN MR
OMEGA PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
16.00
24.00
32.00
40.00
48.00
56.00

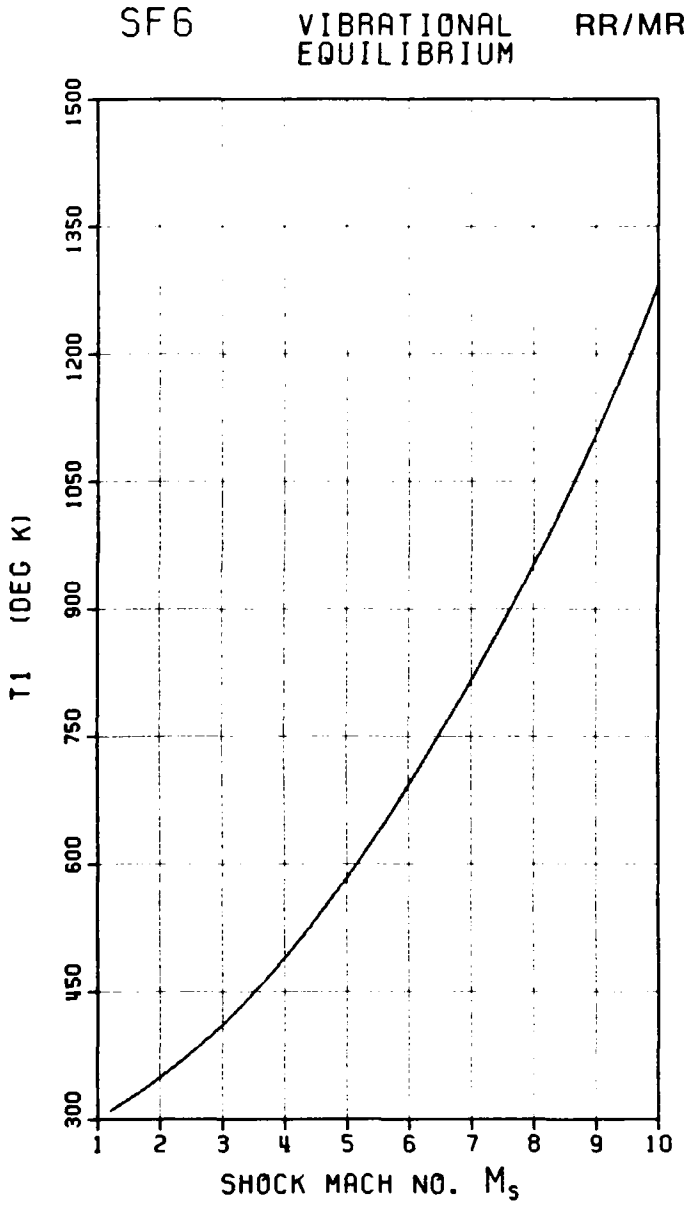
AD-A164 047 TABULAR AND GRAPICAL SOLUTIONS OF REGULAR AND MACH REFLECTIONS IN PSEUDO-.. (U) TORONTO UNIV DOWNSVIEW (ONTARIO) INST FOR AEROSPACE STUDIES T C HU ET AL. 2/3

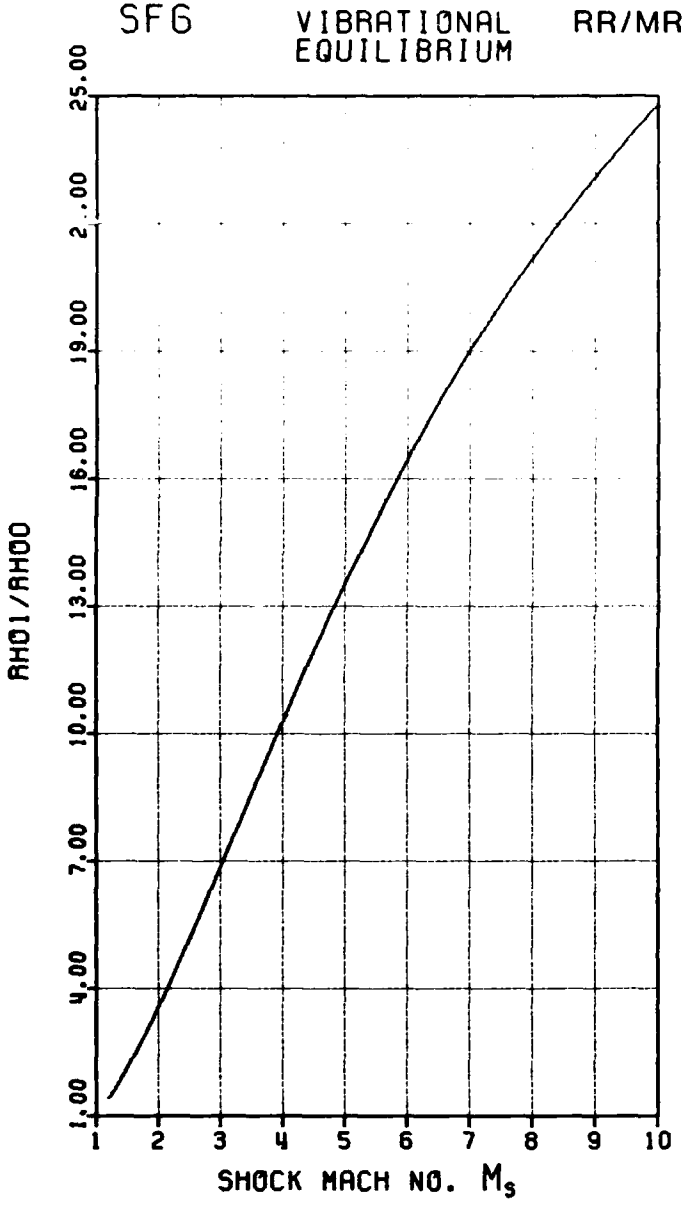
UNCLASSIFIED JUN 85 UTIAS-283-PT-2 AFOSR-TR-85-1231 F/G 20/4 NL

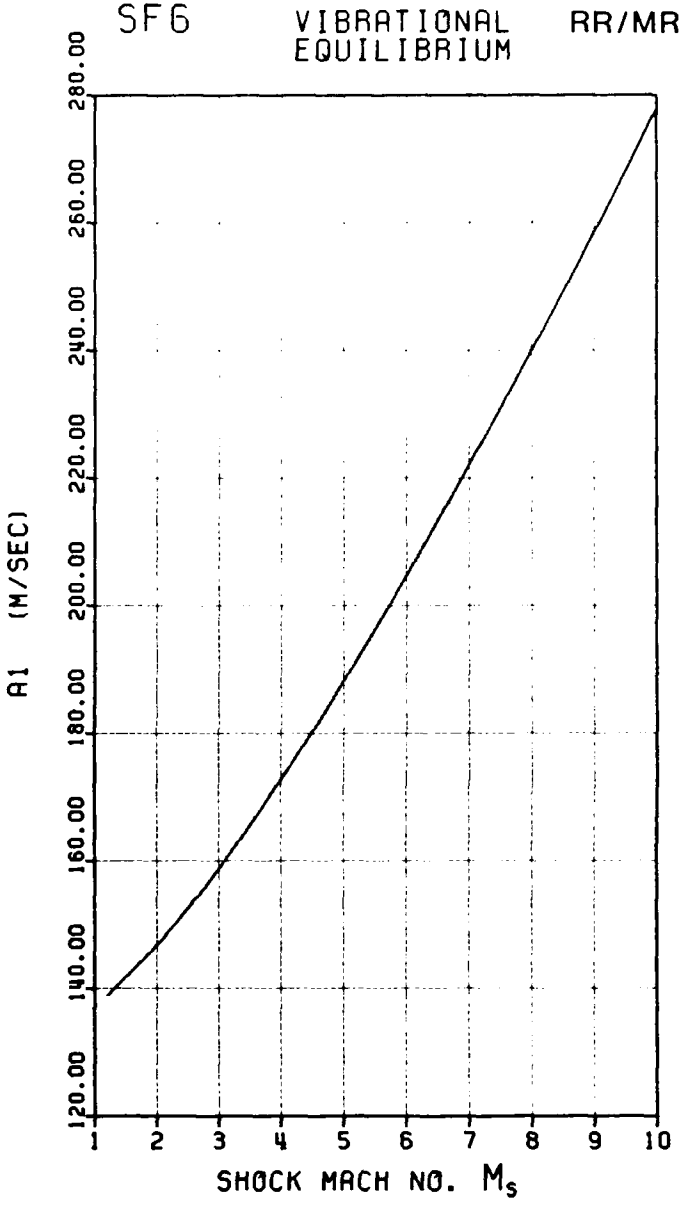


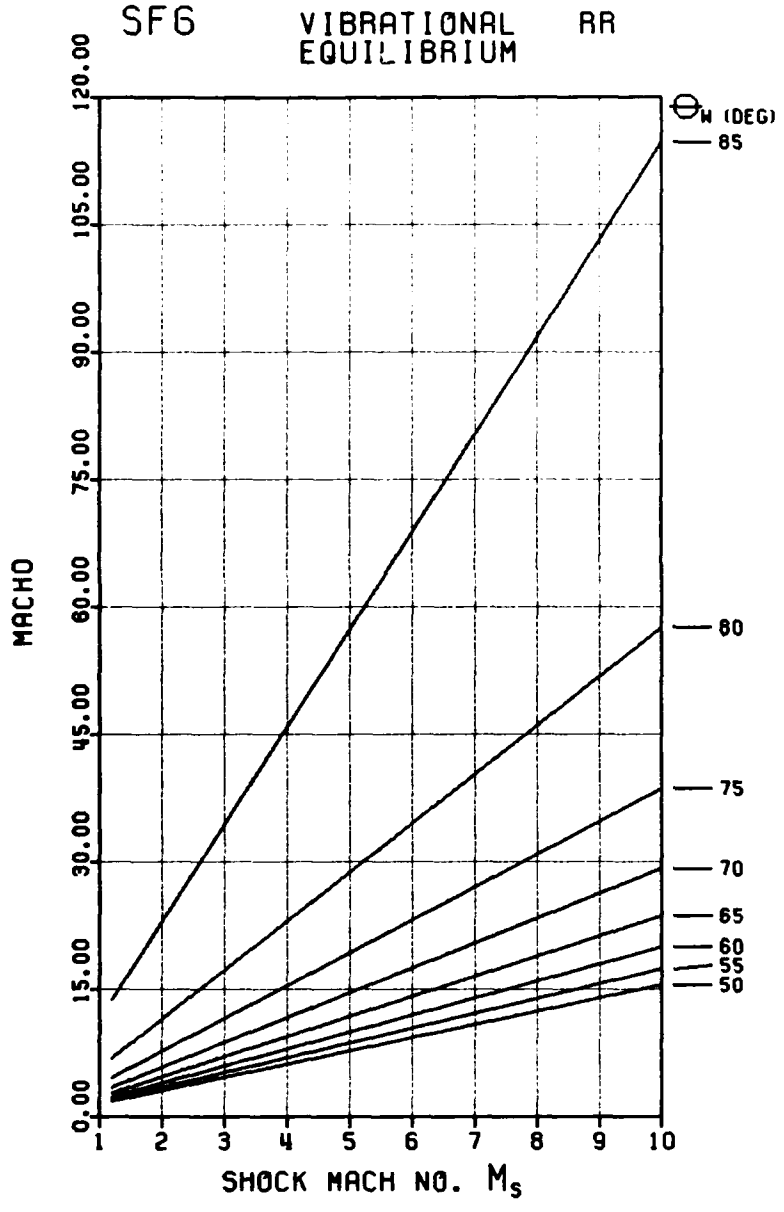


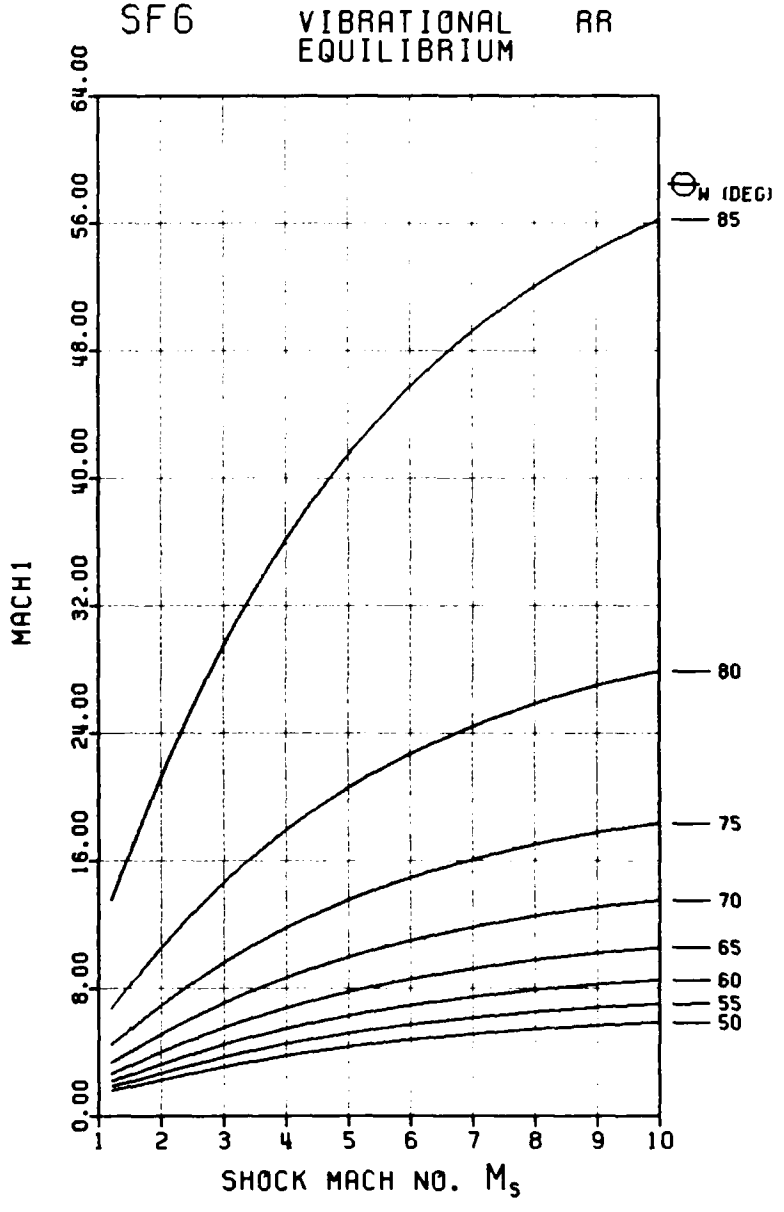

SF6
VIBRATIONAL EQUILIBRIUM
RR/MR
P1/P0
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

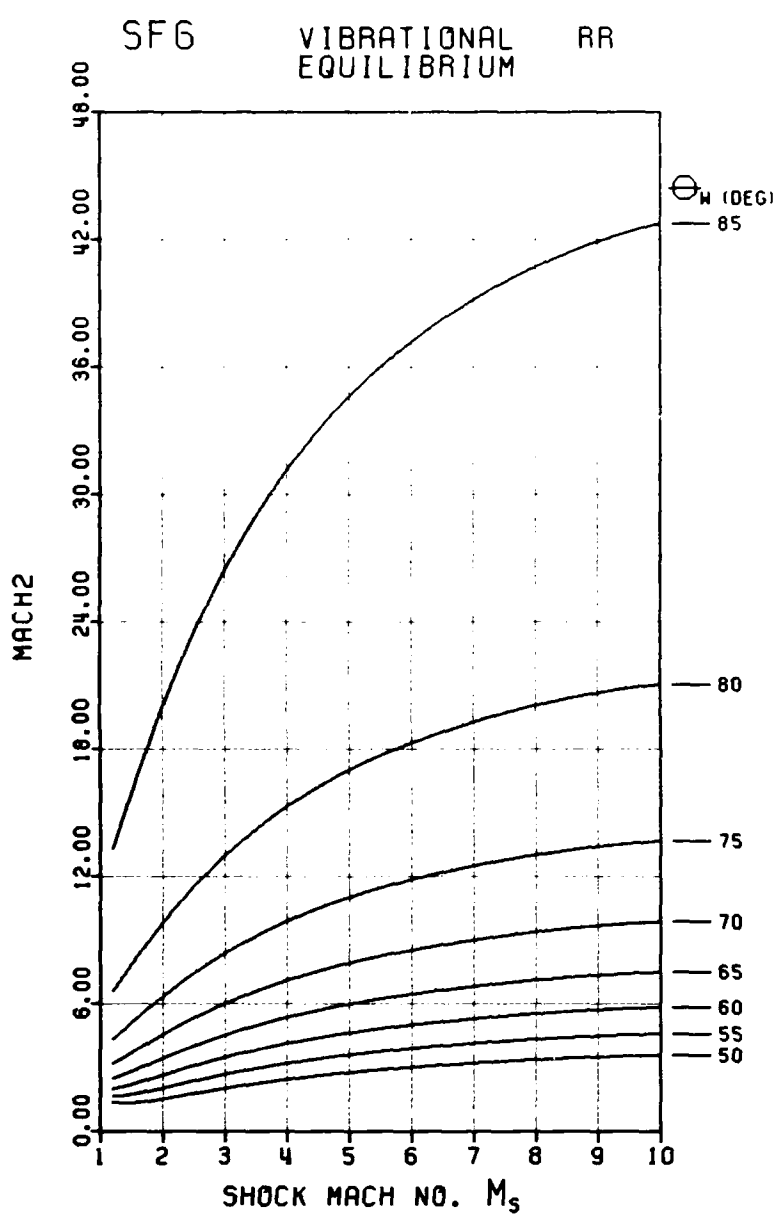

SF6
VIBRATIONAL EQUILIBRIUM
RR/MR
T1 (DEG K)
300
450
600
750
900
1050
1200
1350
1500
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

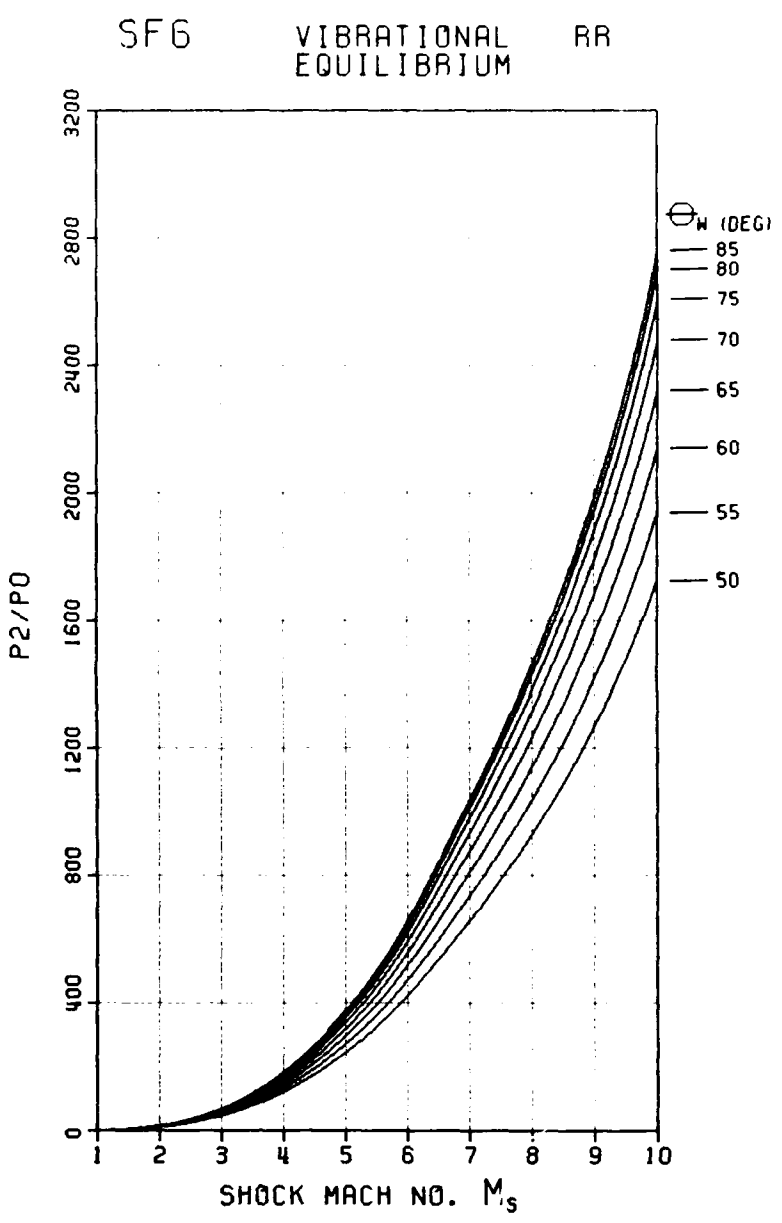

SF6 VIBRATIONAL EQUILIBRIUM RR/MR
RHO1/RHOO
1.00
4.00
7.00
10.00
13.00
16.00
19.00
2..00
25.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

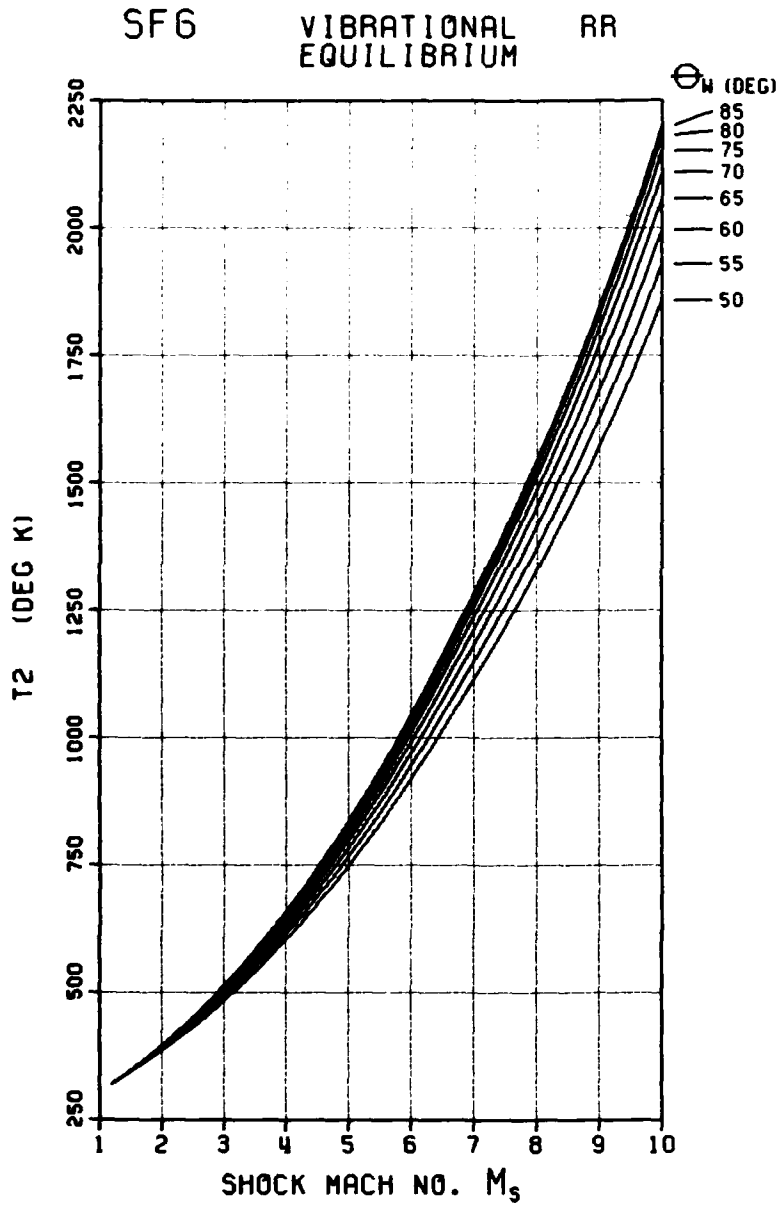

SF6 VIBRATIONAL EQUILIBRIUM RR/MR
A1 (M/SEC)
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

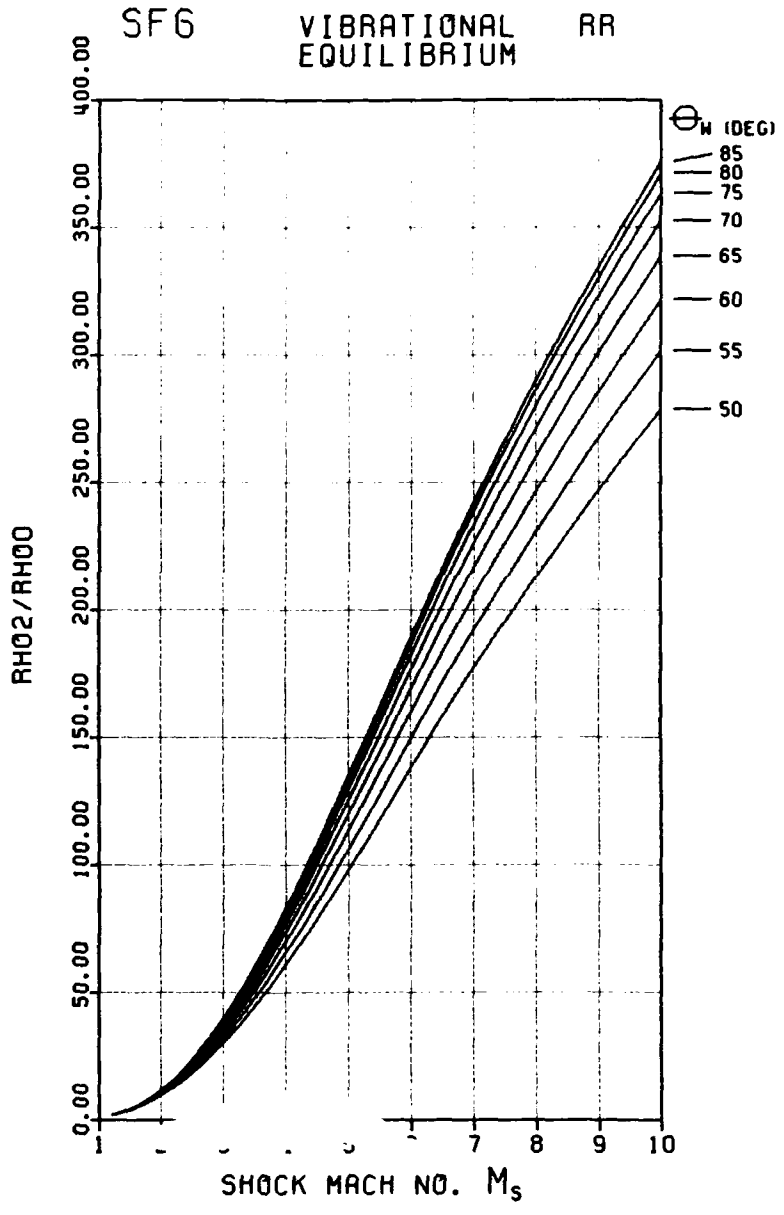

SF6 VIBRATIONAL EQUILIBRIUM RR
MACH0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
1
2
3
4
5
6
7
8
9
10

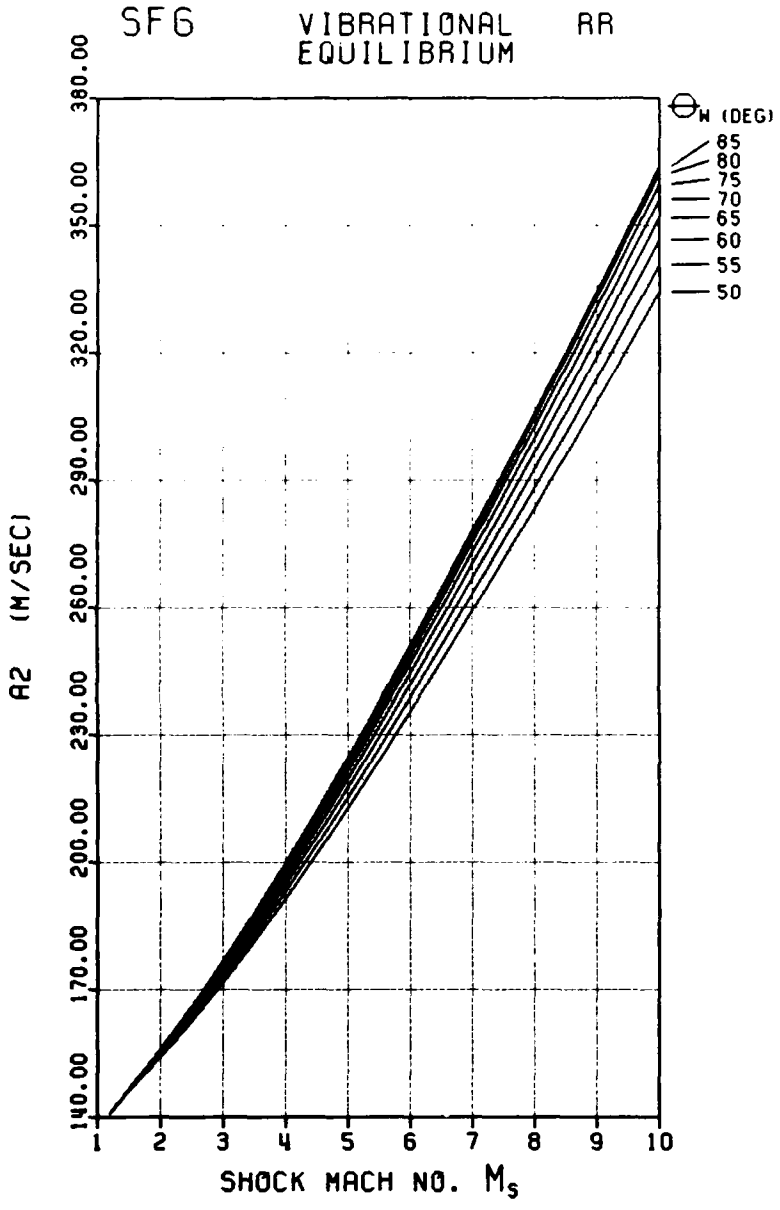

SF6 VIBRATIONAL EQUILIBRIUM RR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
1
2
3
4
5
6
7
8
9
10

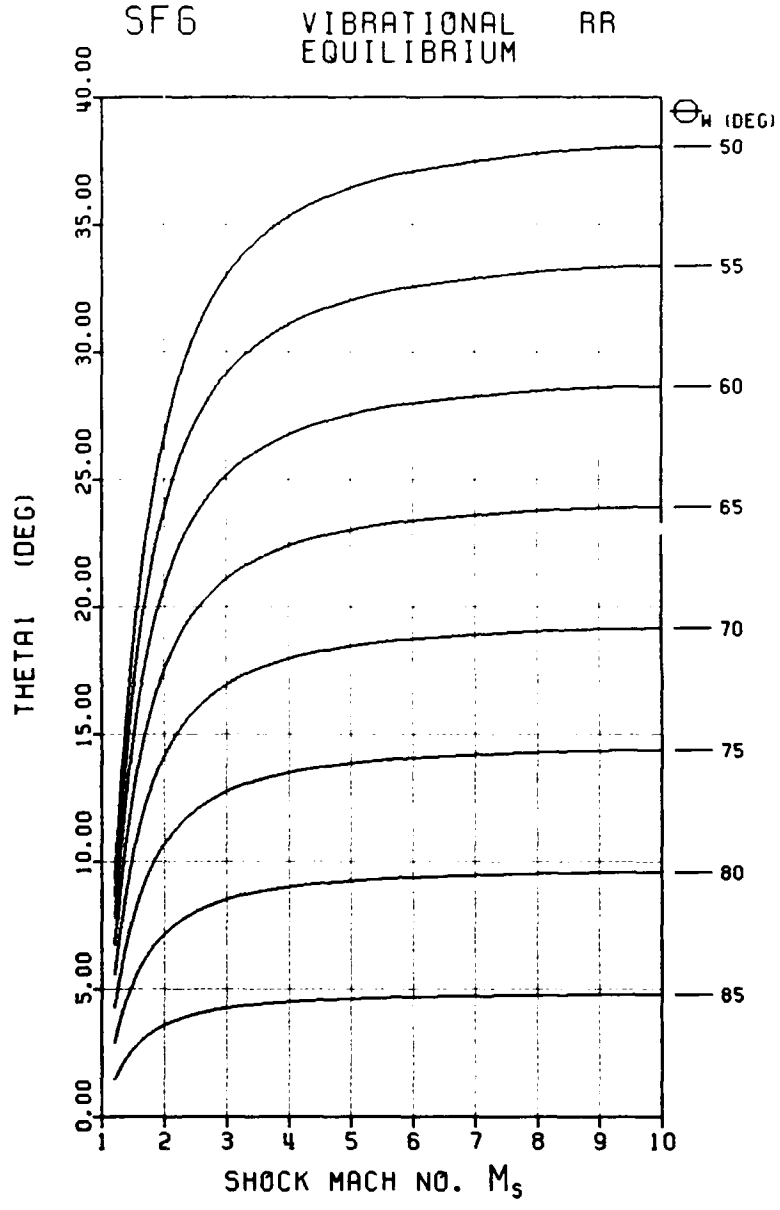

SF6 VIBRATIONAL EQUILIBRIUM RR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
1
2
3
4
5
6
7
8
9
10

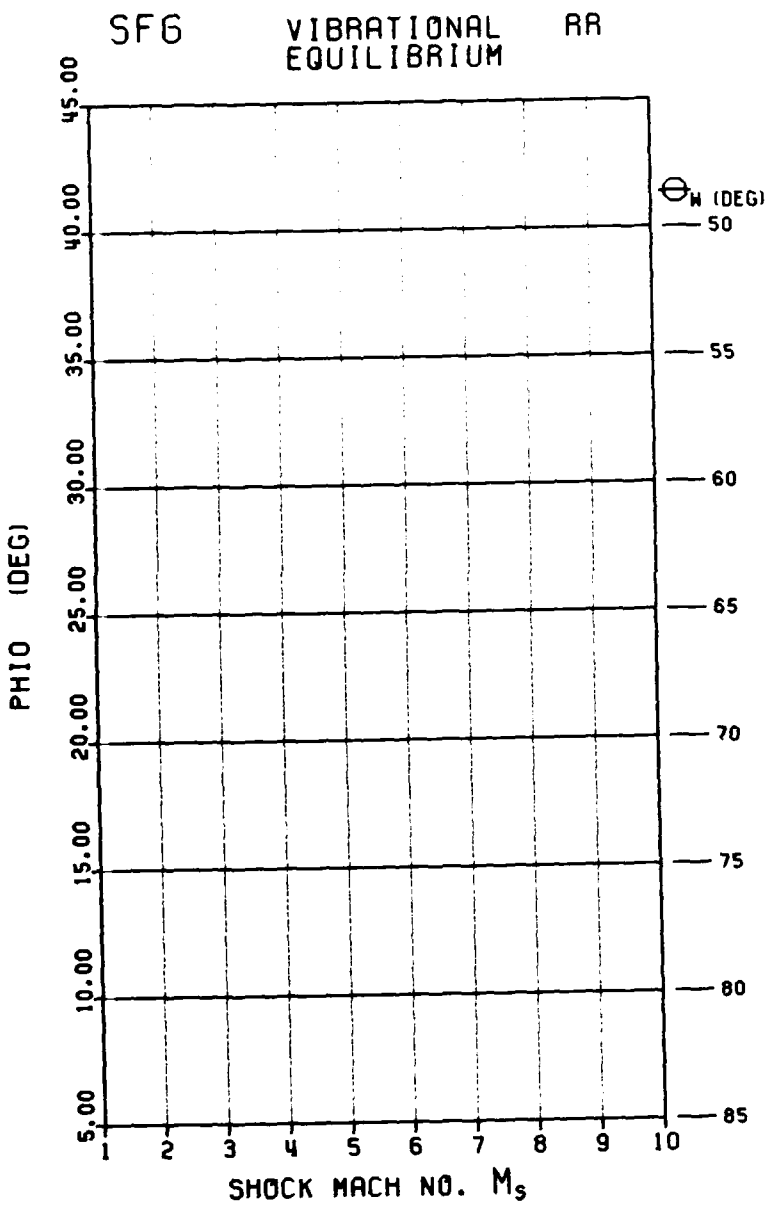

SF6 VIBRATIONAL EQUILIBRIUM RR
P2/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50
0
400
800
1200
1600
2000
2400
2800
3200
1
2
3
4
5
6
7
8
9
10

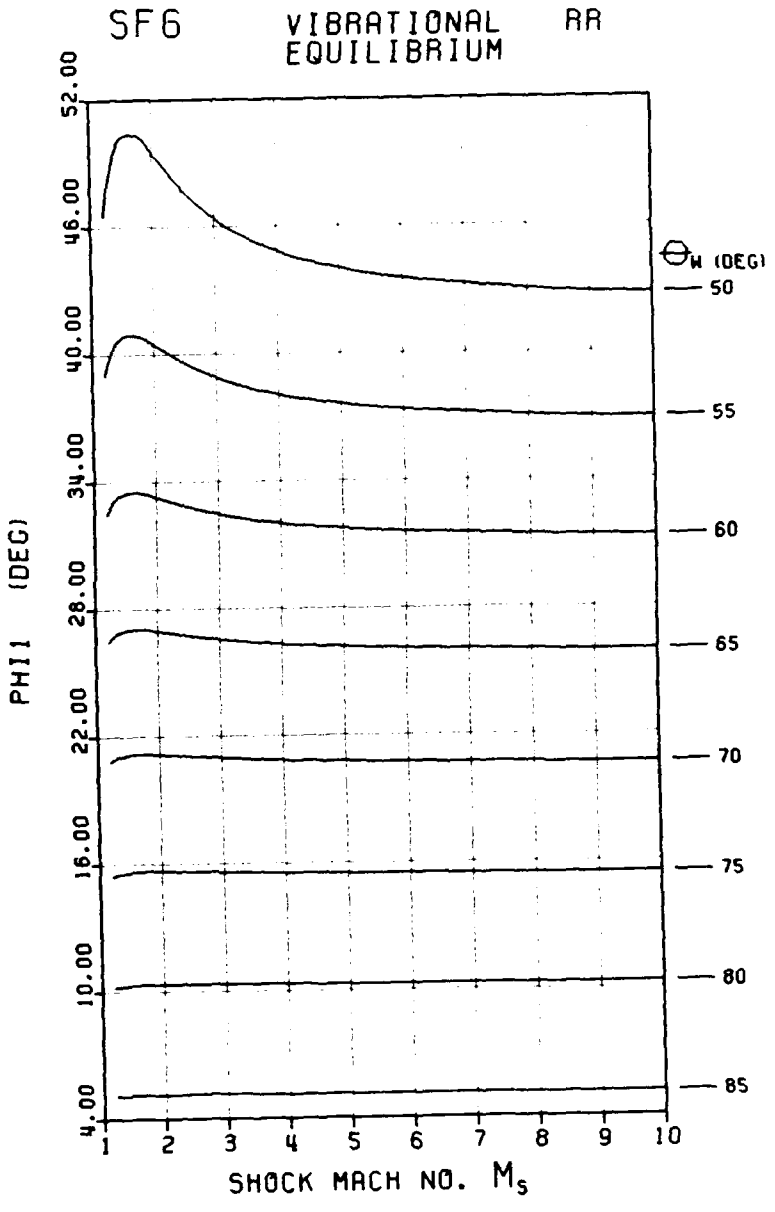

SF6
VIBRATIONAL EQUILIBRIUM
RR
Θ_W (DEG)
85
80
75
70
65
60
55
50
T2 (DEG K)
250
500
750
1000
1250
1500
1750
2000
2250
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

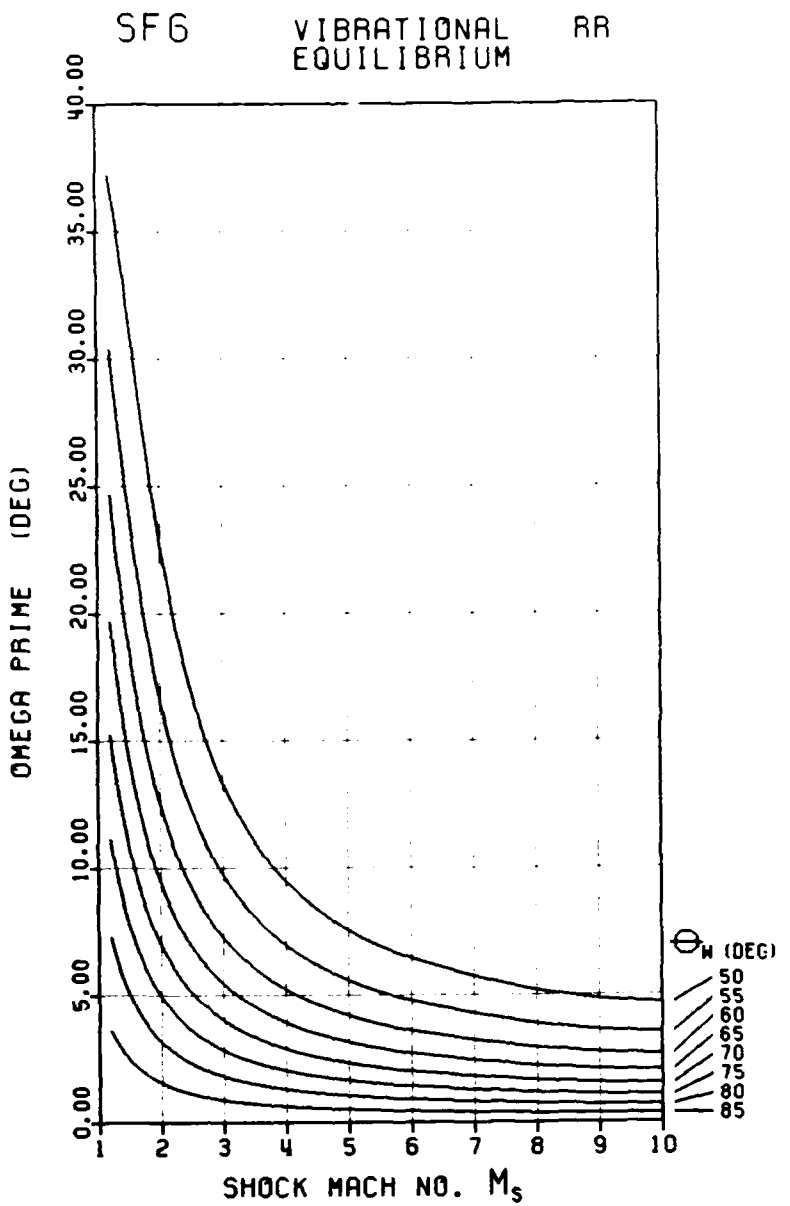

SF6
VIBRATIONAL EQUILIBRIUM
RR
Θ_W (DEG)
85
80
75
70
65
60
55
50
RH02/RH00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
7
8
9
10
SHOCK MACH NO. M_S

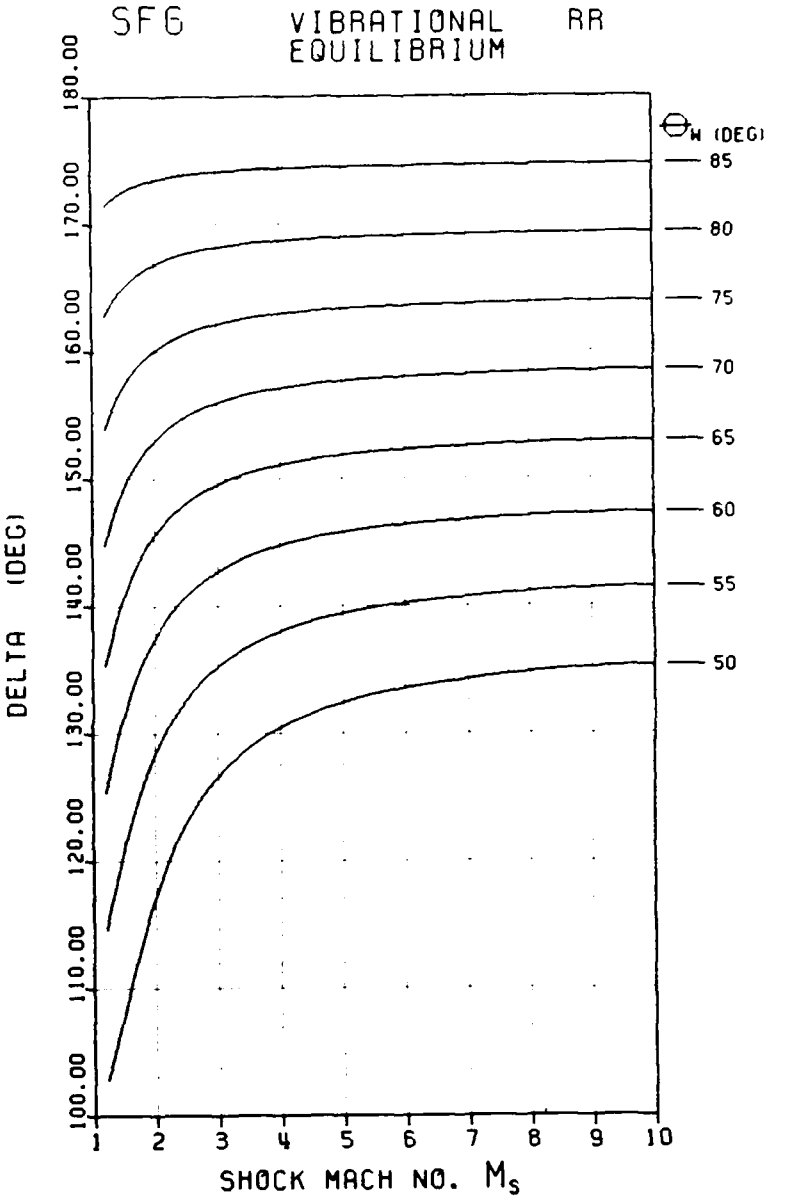

SF6 VIBRATIONAL RR
EQUILIBRIUM
A2 (M/SEC)
140.00
170.00
200.00
230.00
260.00
290.00
320.00
350.00
380.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

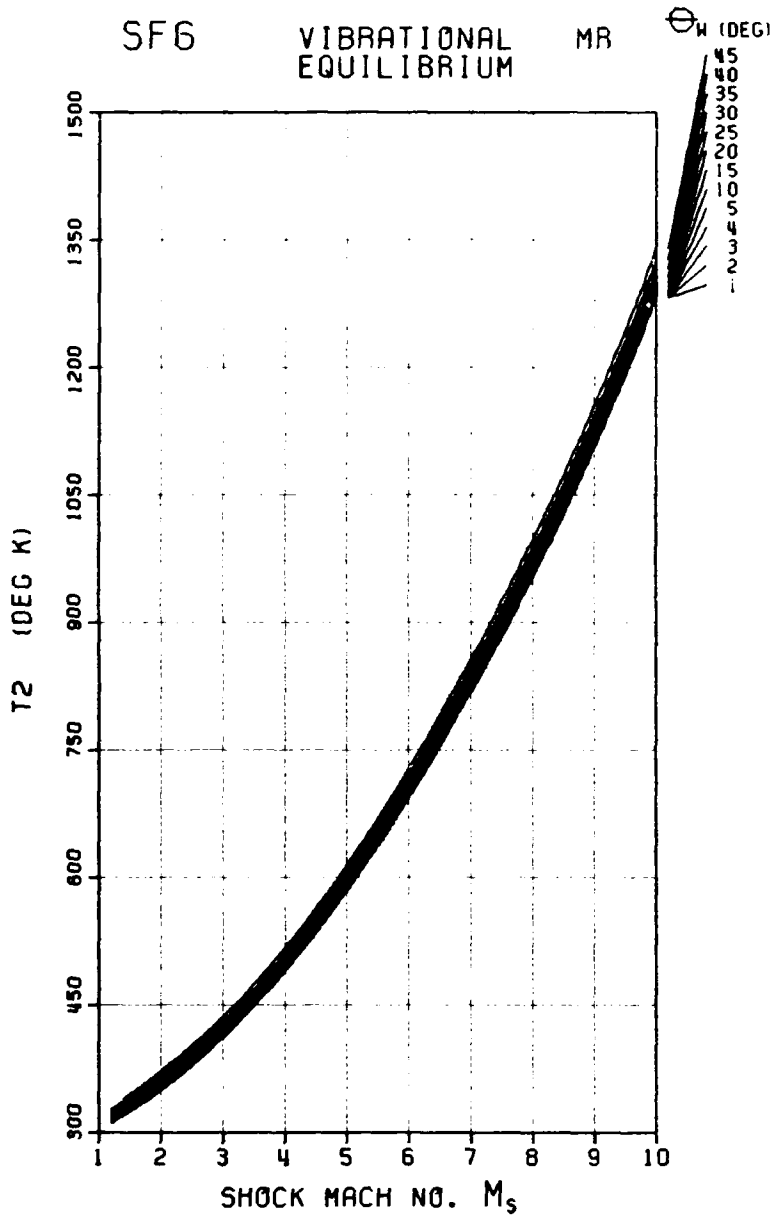

SF6 VIBRATIONAL RR
EQUILIBRIUM
THETA1 (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
55
60
65
70
75
80
85

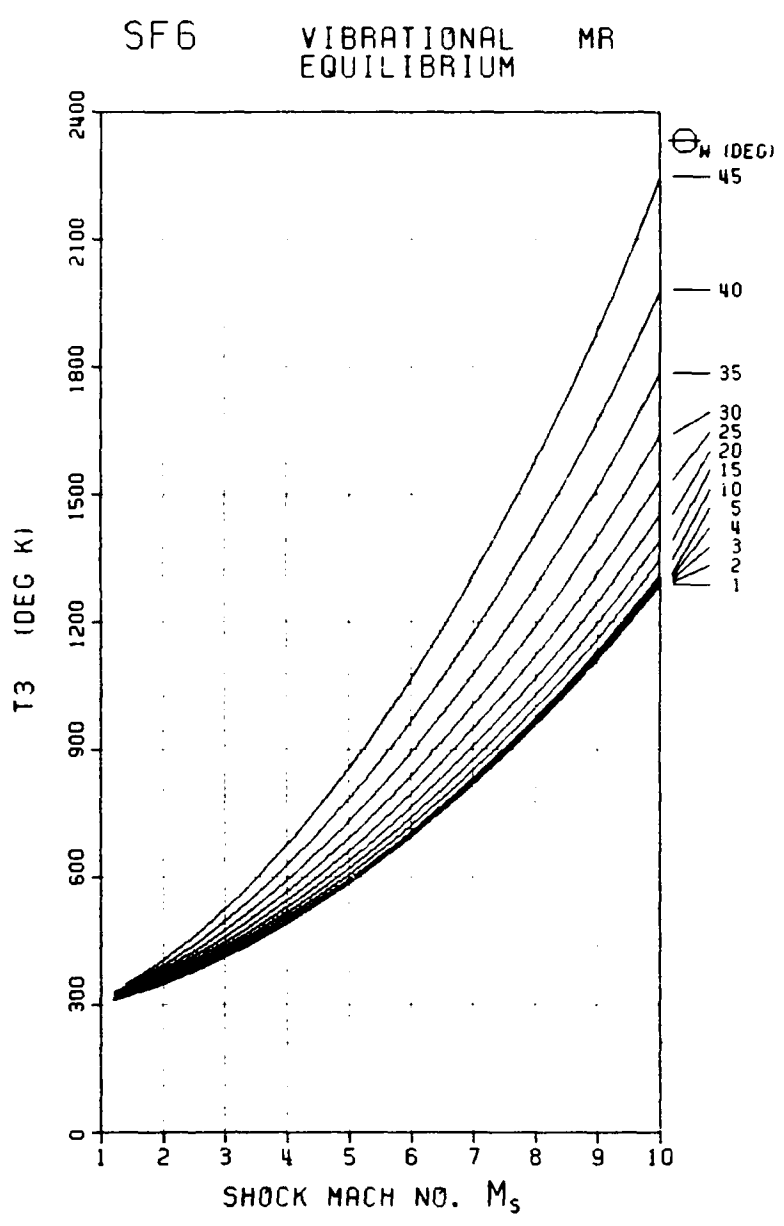

SF6 VIBRATIONAL EQUILIBRIUM RR
PHI0 (DEG)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
θW (DEG)
50
55
60
65
70
75
80
85
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. Ms

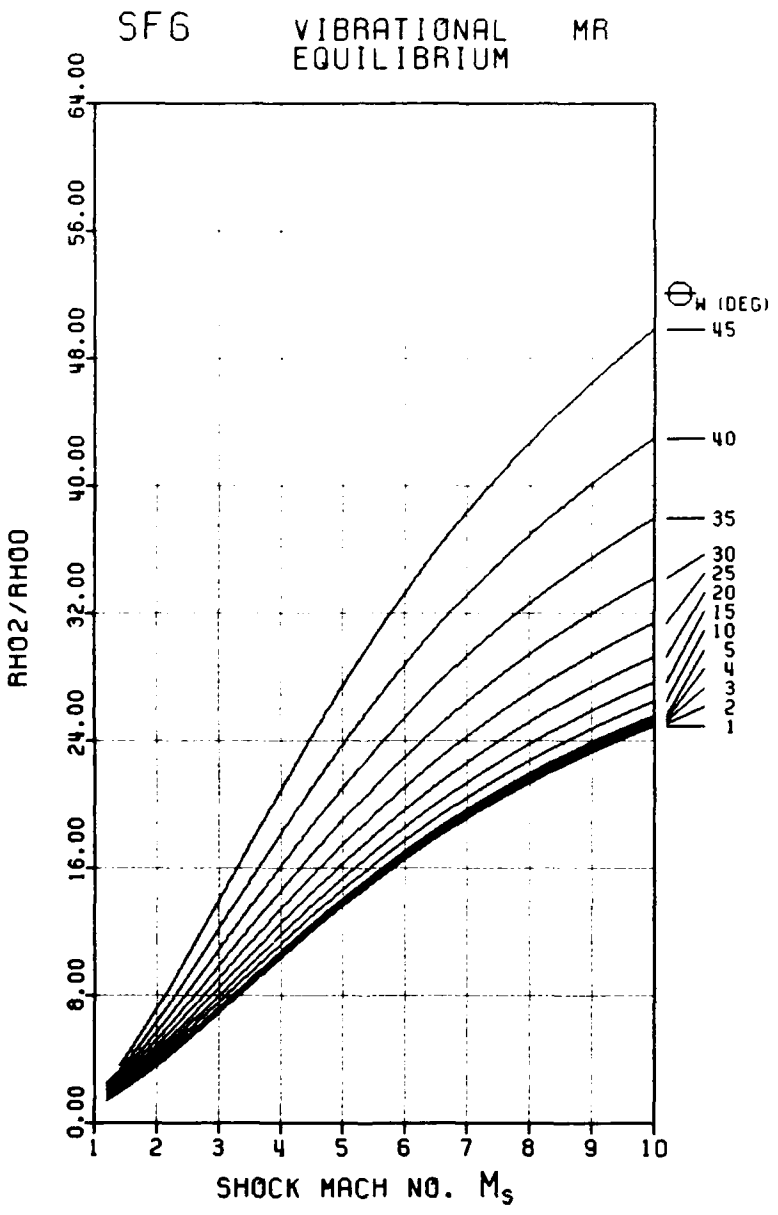

SF6 VIBRATIONAL EQUILIBRIUM RR
PHI1 (DEG)
52.00
46.00
40.00
34.00
28.00
22.00
16.00
10.00
4.00
θW (DEG)
50
55
60
65
70
75
80
85
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. Ms

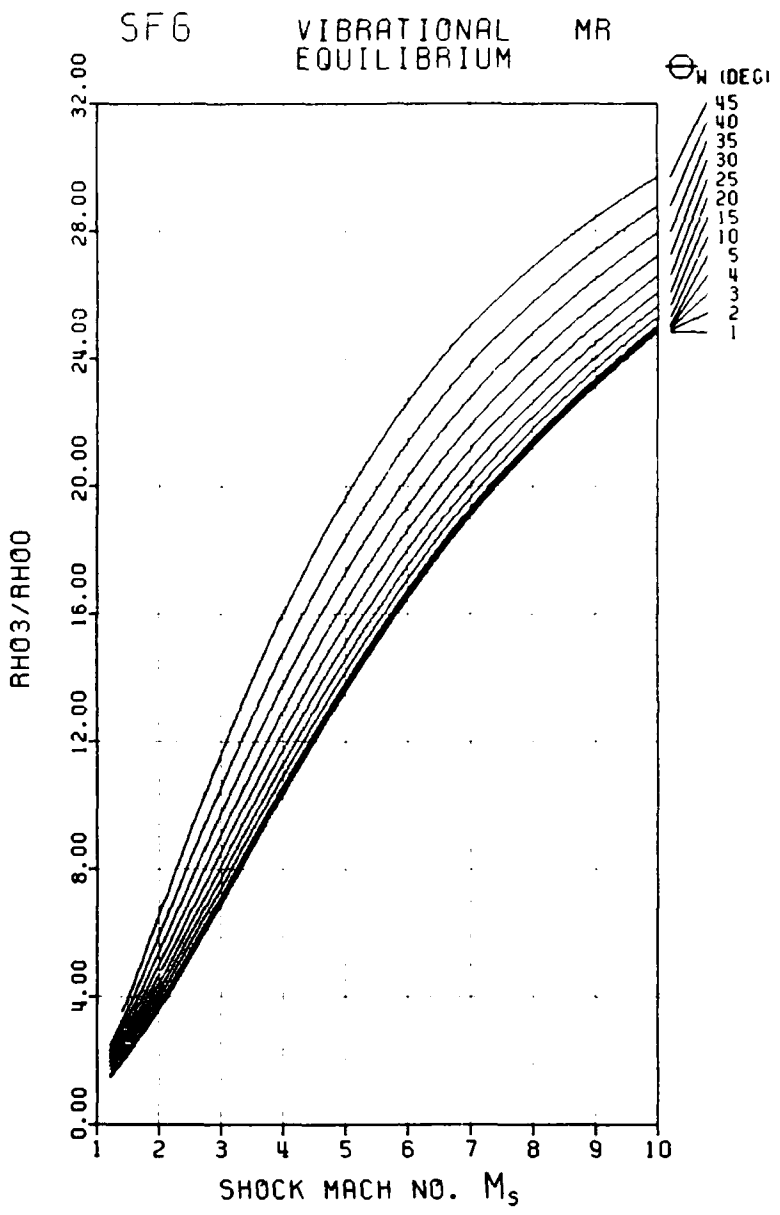

SF6 VIBRATIONAL EQUILIBRIUM RR
OMEGA PRIME (DEG)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
55
60
65
70
75
80
85

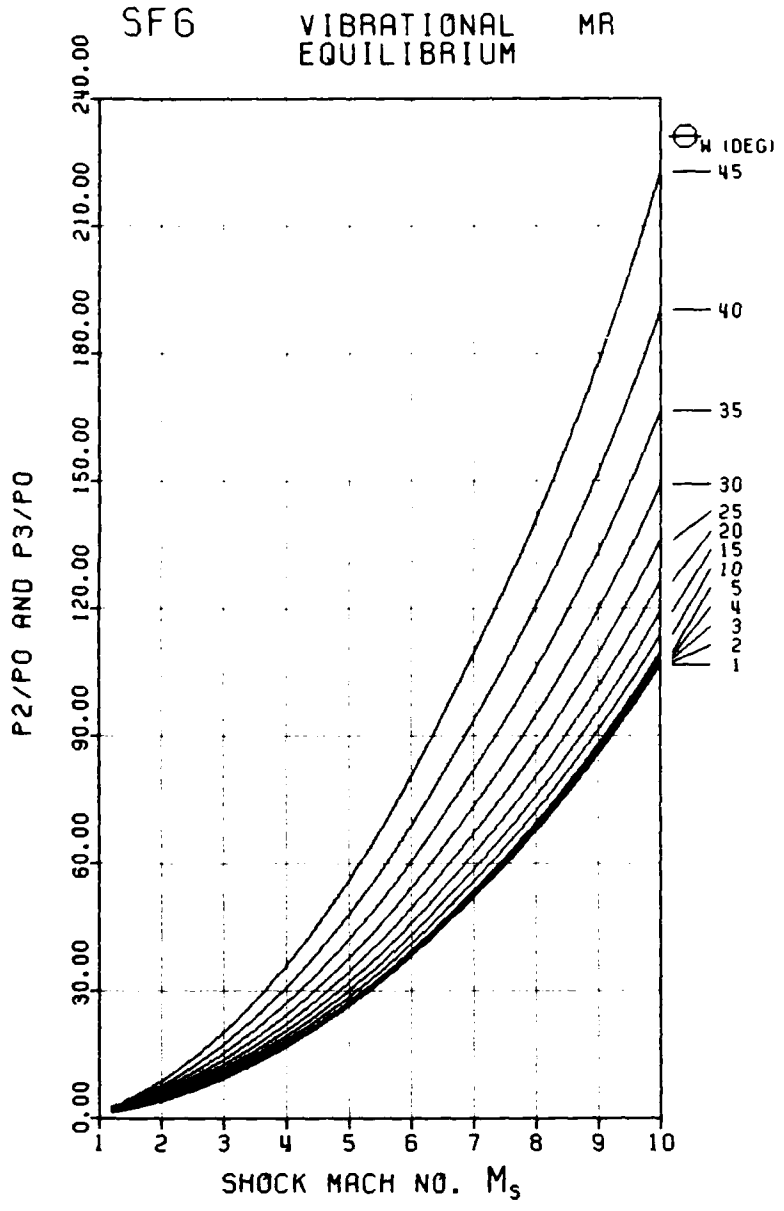

SF6 VIBRATIONAL EQUILIBRIUM RR
DELTA (DEG)
180.00
170.00
160.00
150.00
140.00
130.00
120.00
110.00
100.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
85
80
75
70
65
60
55
50

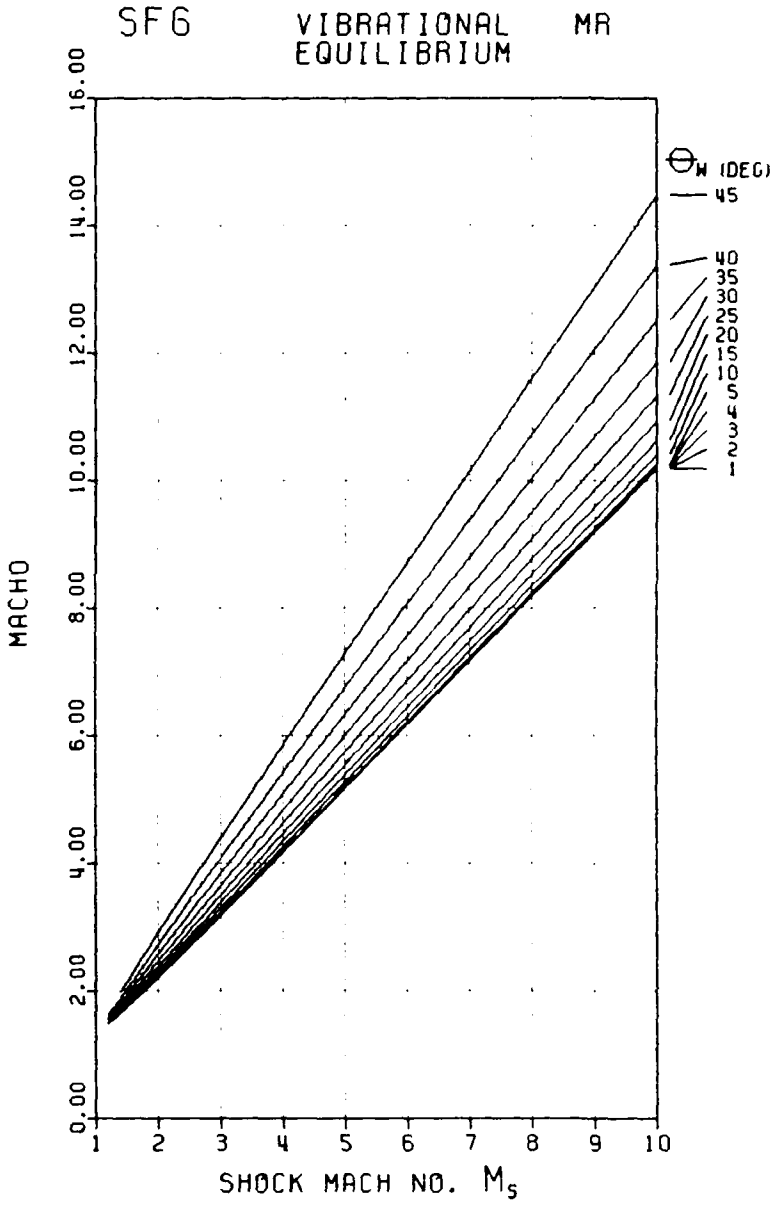

SF6
VIBRATIONAL EQUILIBRIUM
MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
T2 (DEG K)
300
450
600
750
900
1050
1200
1350
1500
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

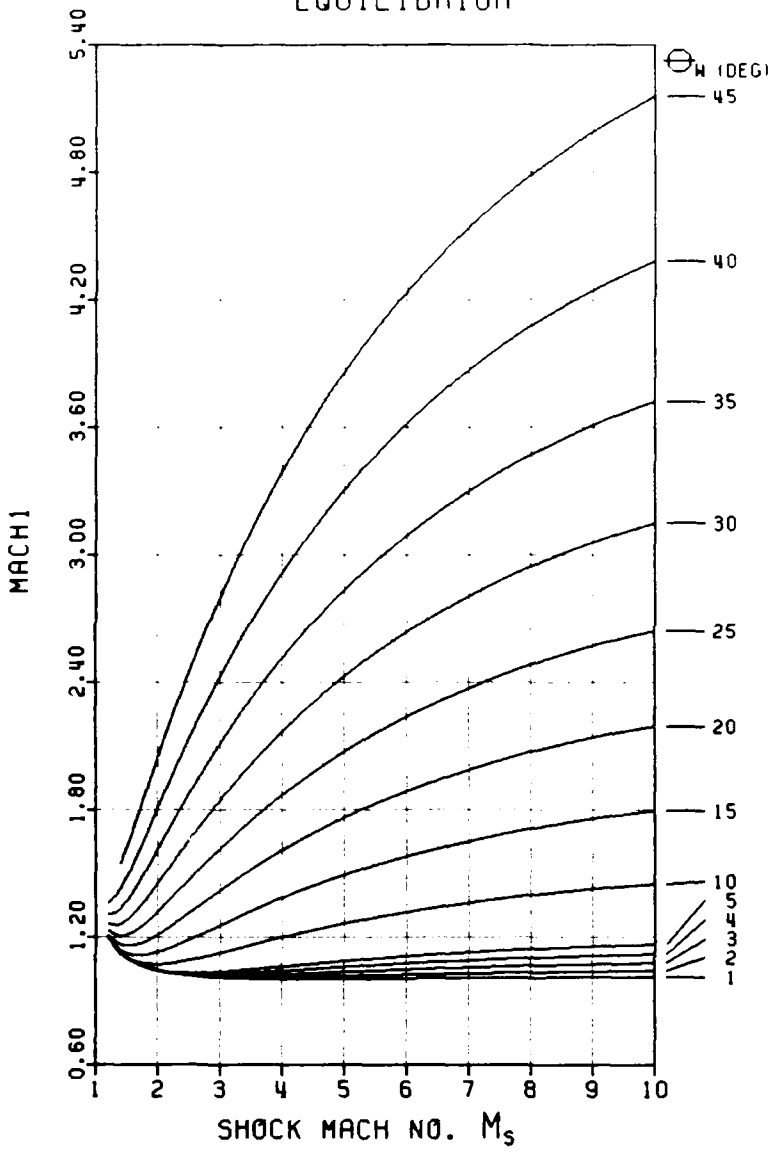

SF6
VIBRATIONAL EQUILIBRIUM
MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
T3 (DEG K)
0
300
600
900
1200
1500
1800
2100
2400
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

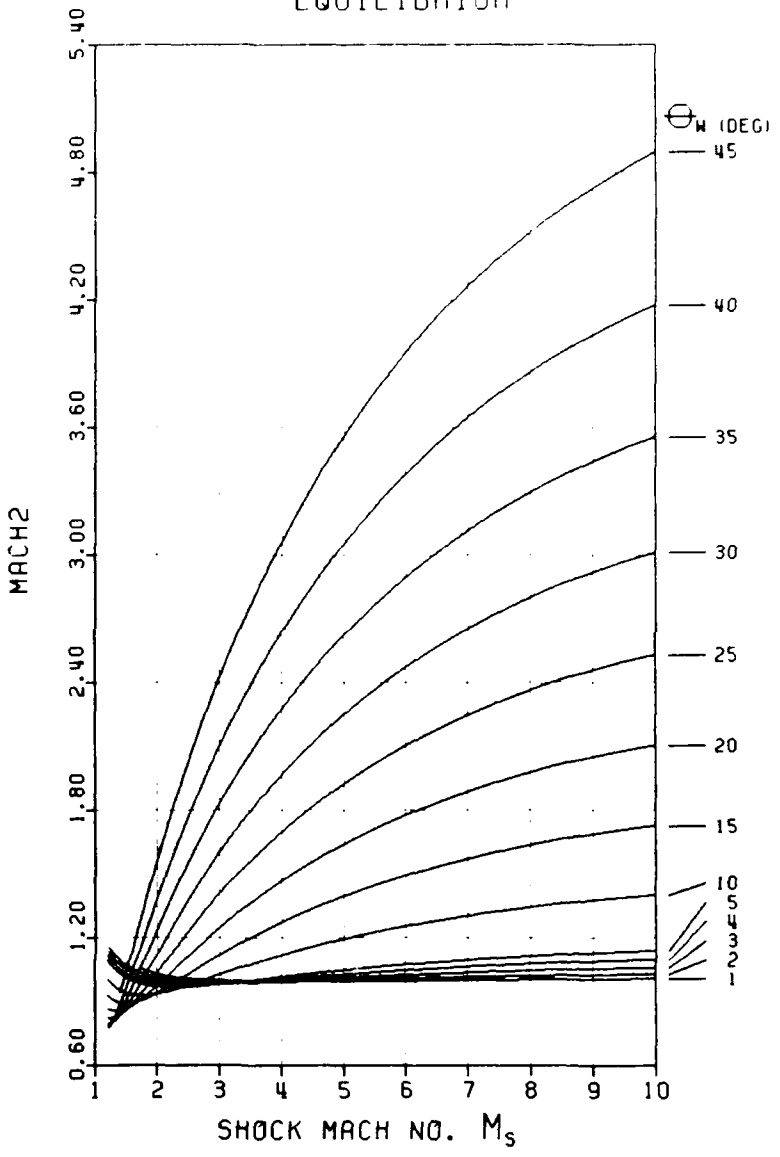

SF6 VIBRATIONAL EQUILIBRIUM MR
RHO2/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
1
2
3
4
5
6
7
8
9
10

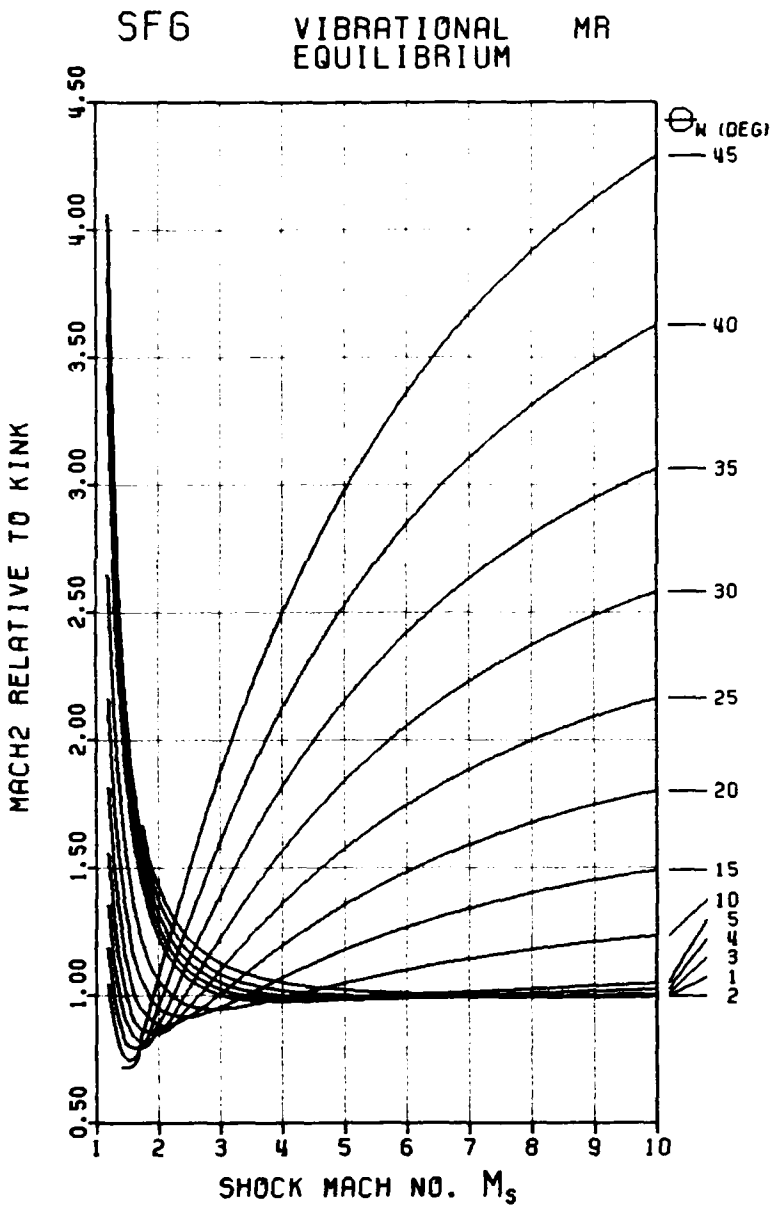

SF6 VIBRATIONAL EQUILIBRIUM MR
RHO3/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
1
2
3
4
5
6
7
8
9
10

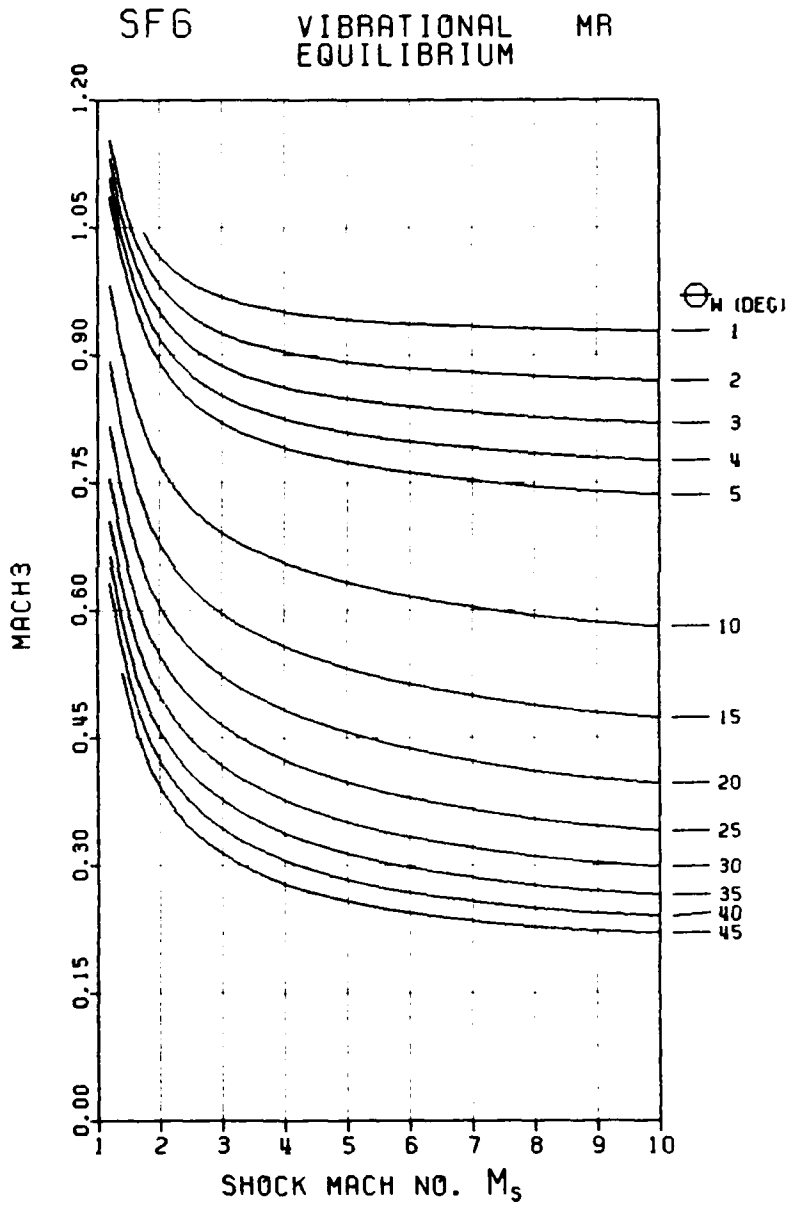

SF6 VIBRATIONAL EQUILIBRIUM MR
P2/PO AND P3/PO
0.00
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

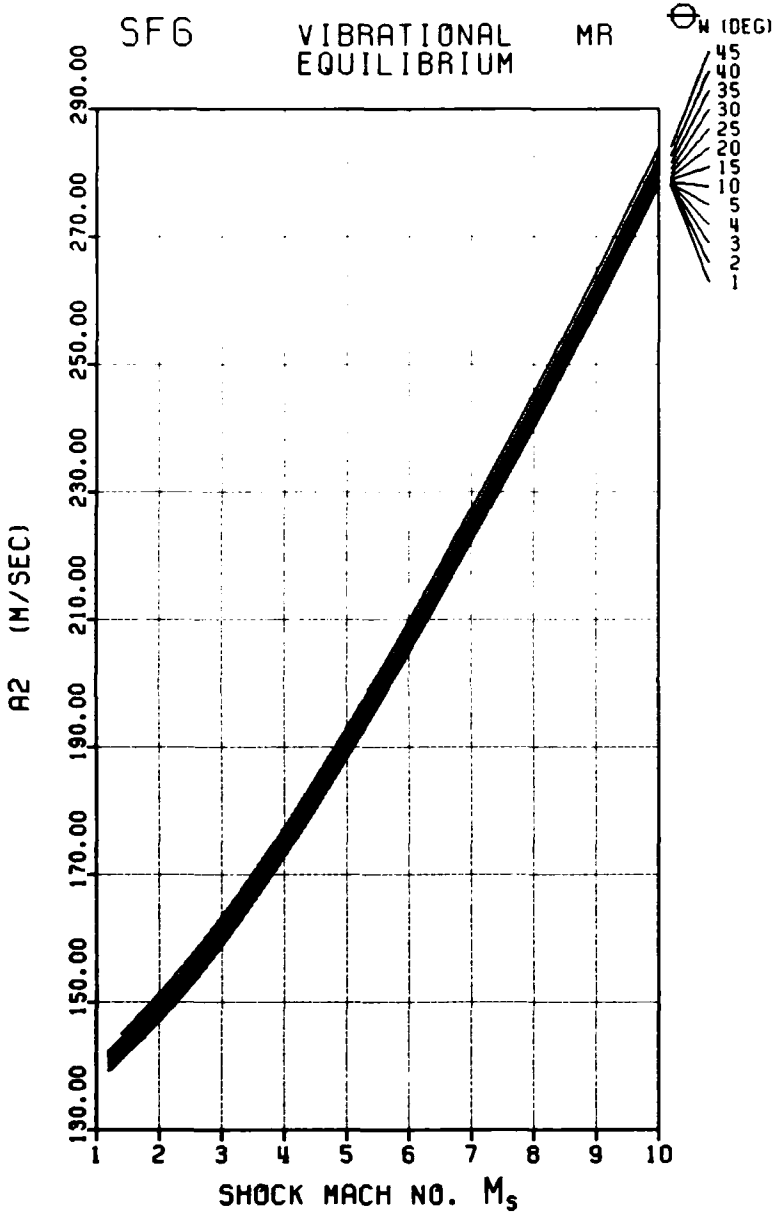

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

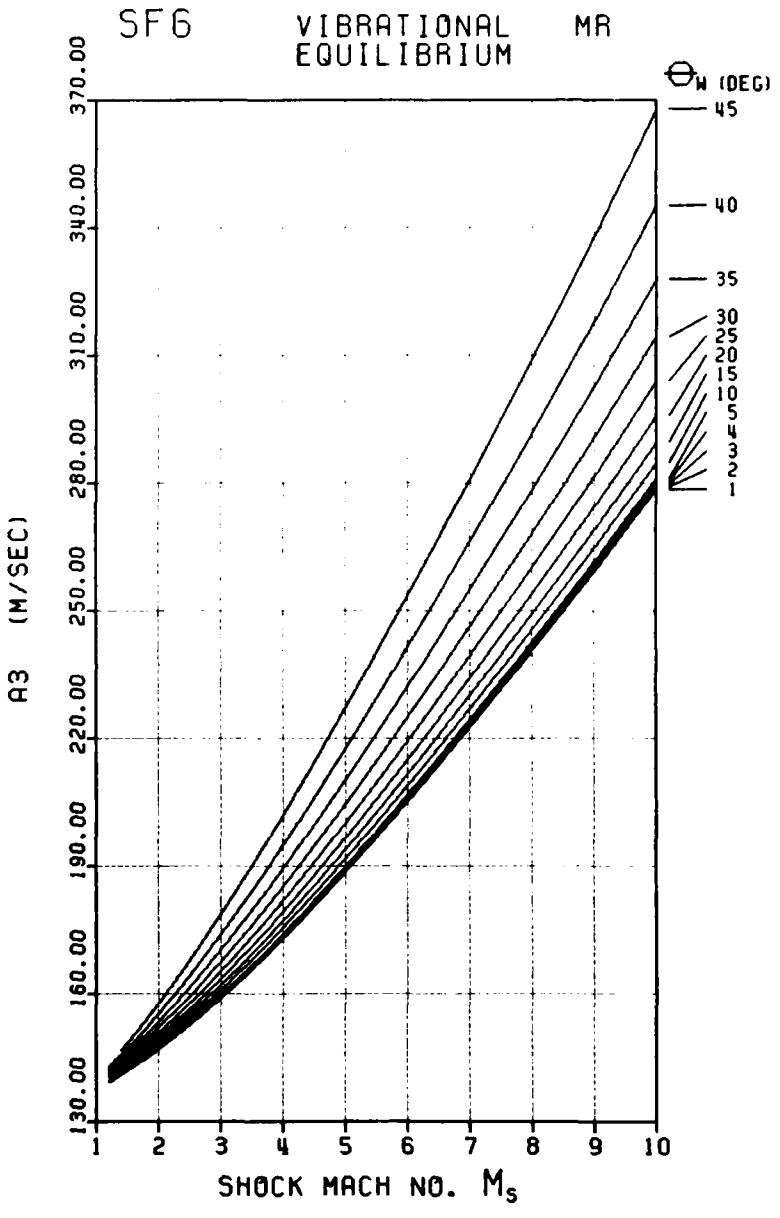

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH1
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.60
1.20
1.80
2.40
3.00
3.60
4.20
4.80
5.40
1
2
3
4
5
6
7
8
9
10

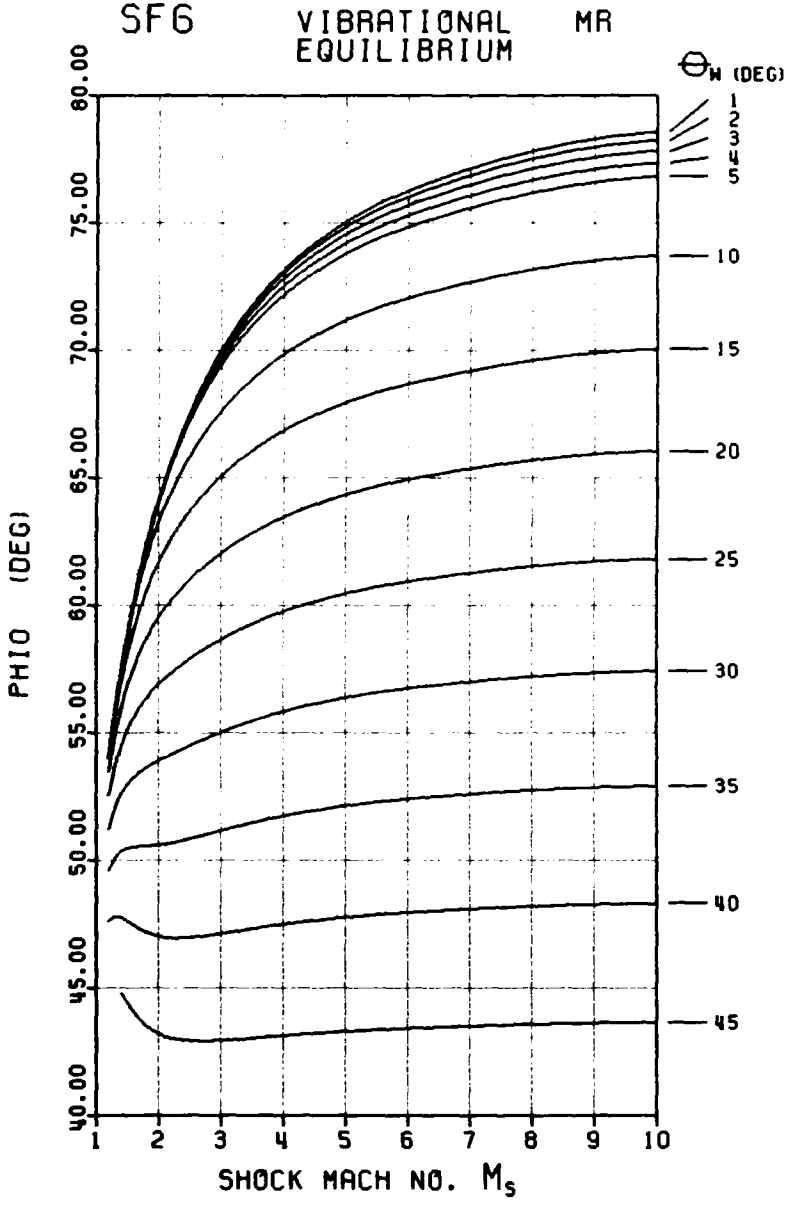

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH2
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
0.60
1.20
1.80
2.40
3.00
3.60
4.20
4.80
5.40
1
2
3
4
5
6
7
8
9
10

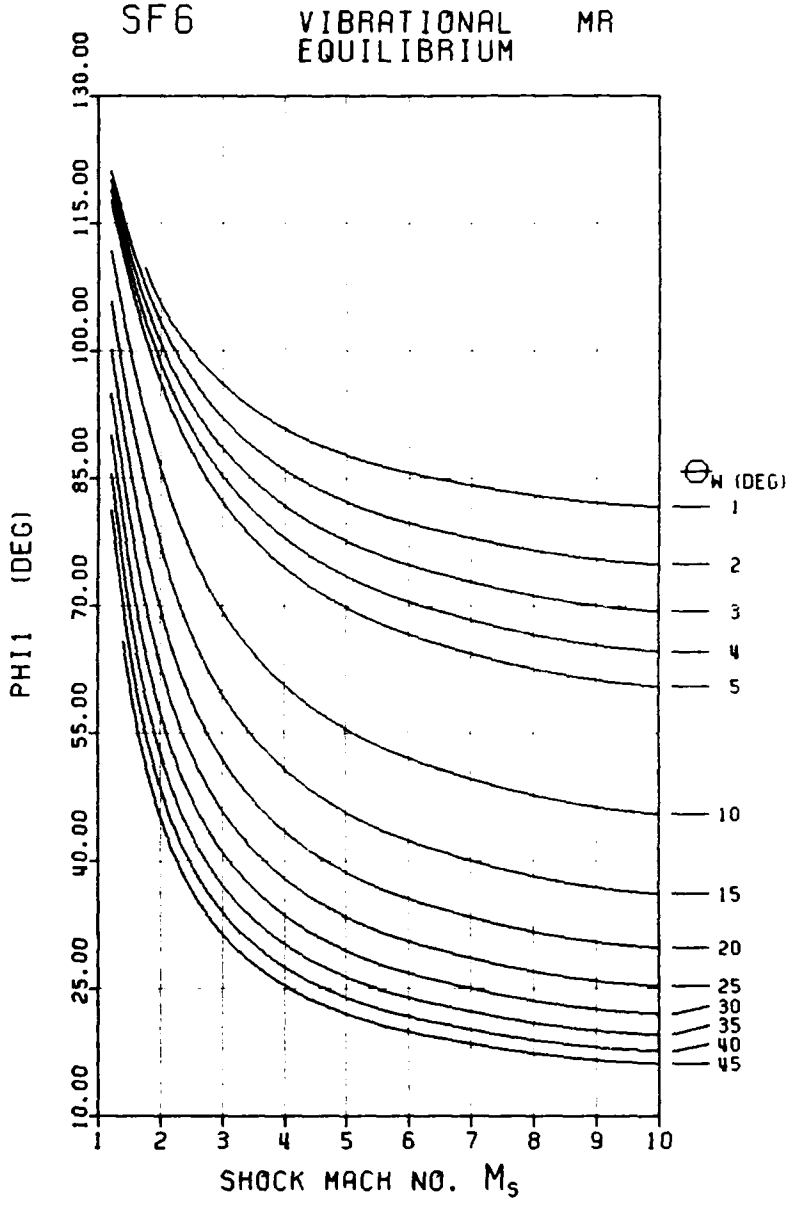

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH2 RELATIVE TO KINK
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
1
2

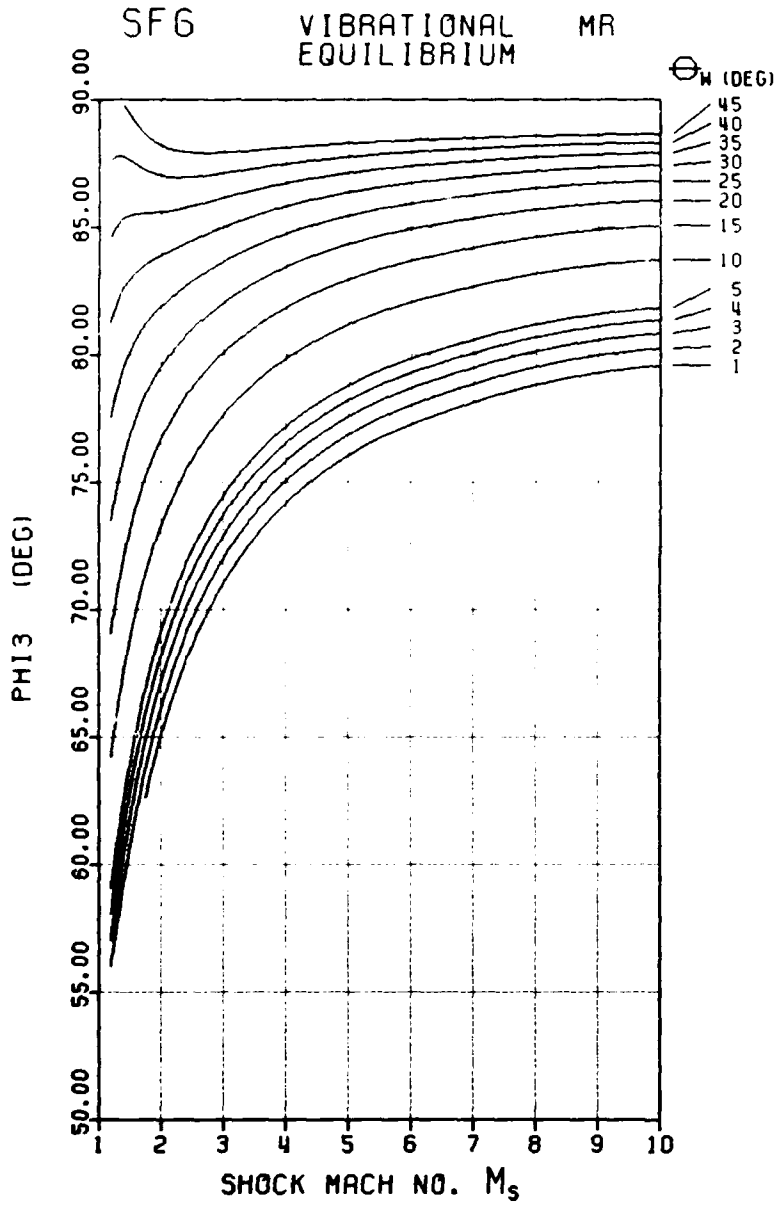

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH3
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

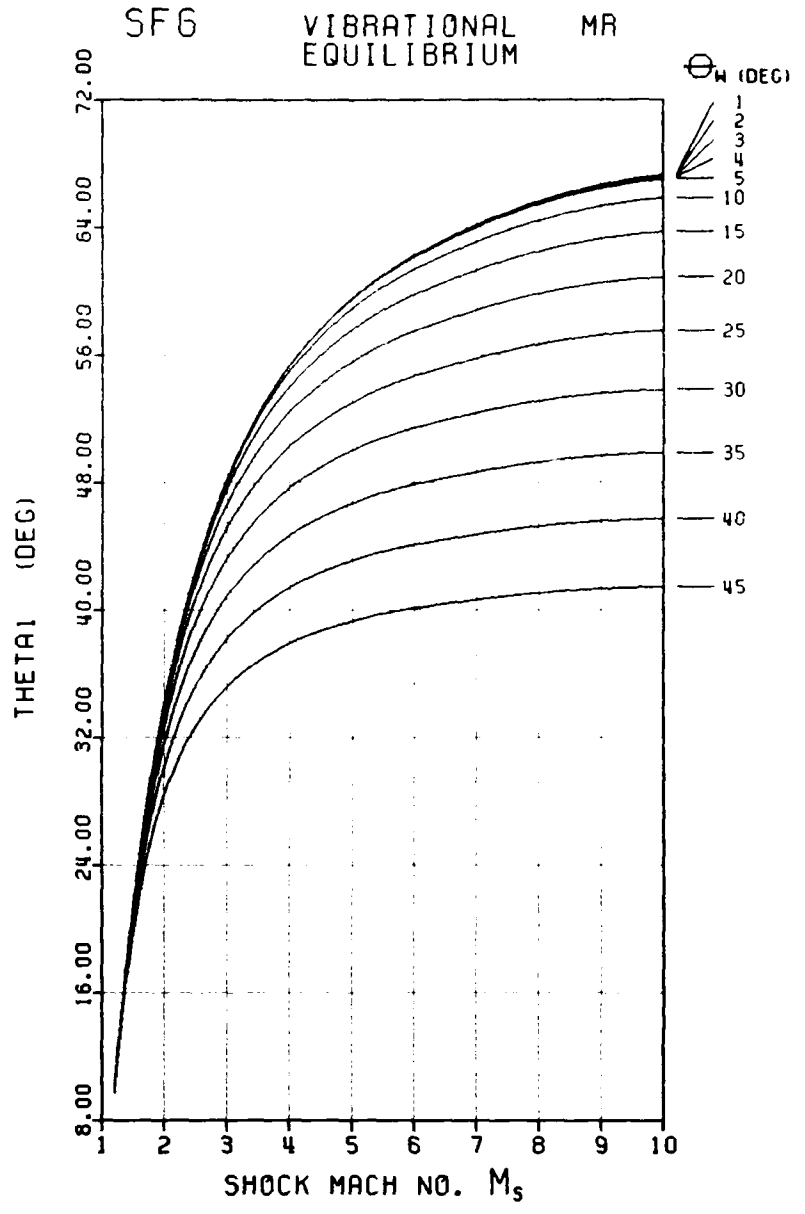

SF6
VIBRATIONAL EQUILIBRIUM
MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A2 (M/SEC)
290.00
270.00
250.00
230.00
210.00
190.00
170.00
150.00
130.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

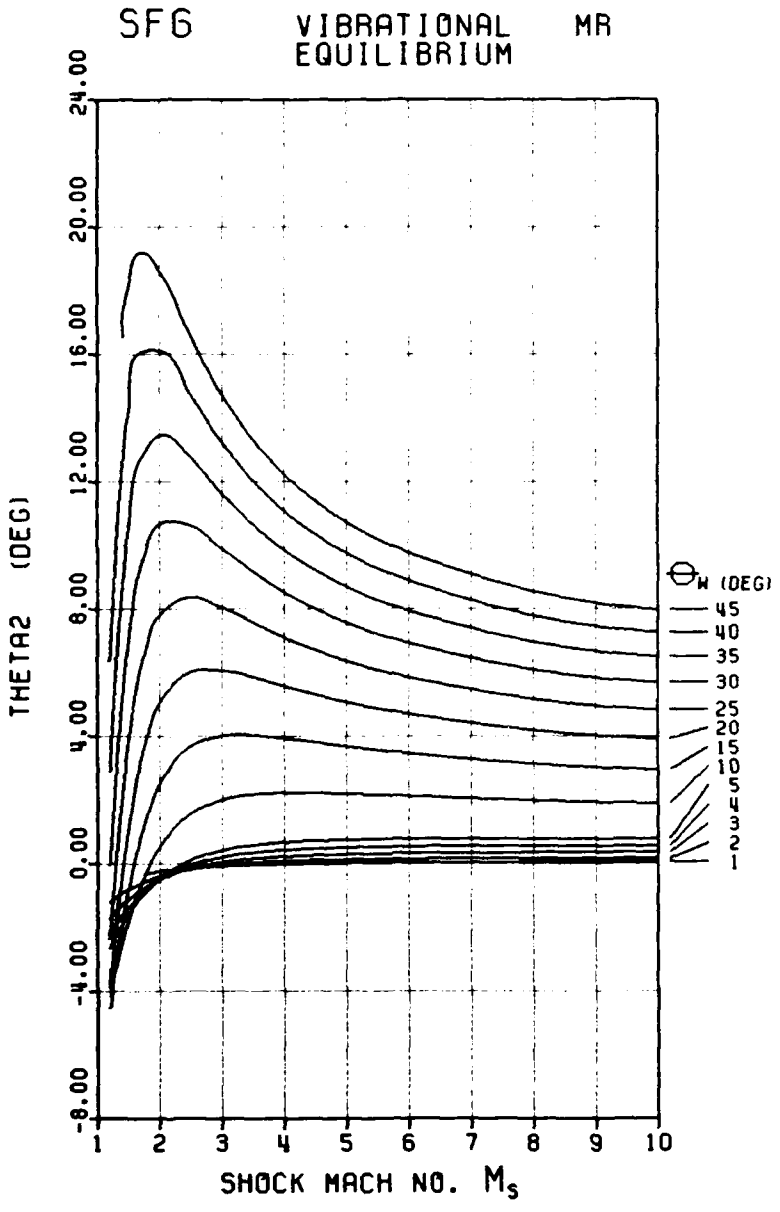

SF6
VIBRATIONAL EQUILIBRIUM
MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
A3 (M/SEC)
370.00
340.00
310.00
280.00
250.00
220.00
190.00
160.00
130.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S

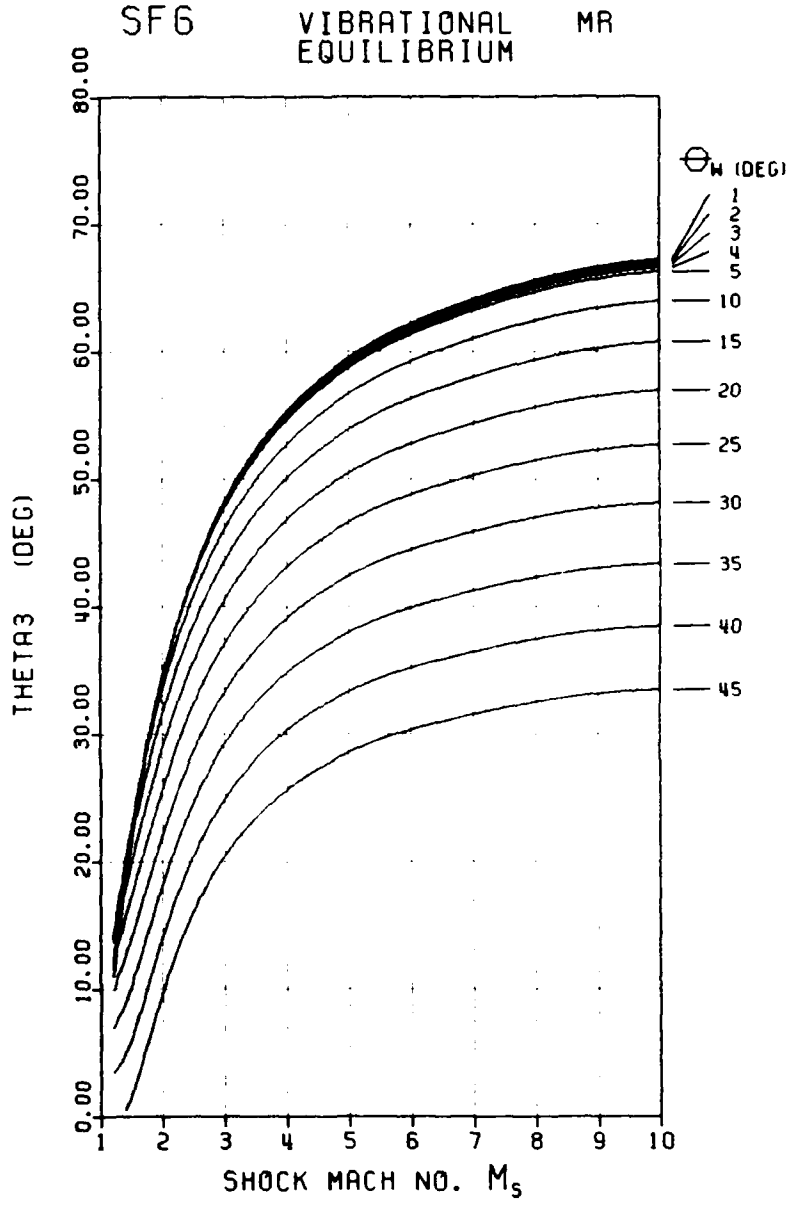

SF6 VIBRATIONAL EQUILIBRIUM MR
PHI0 (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
80.00
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 10 15 20 25 30 35 40 45

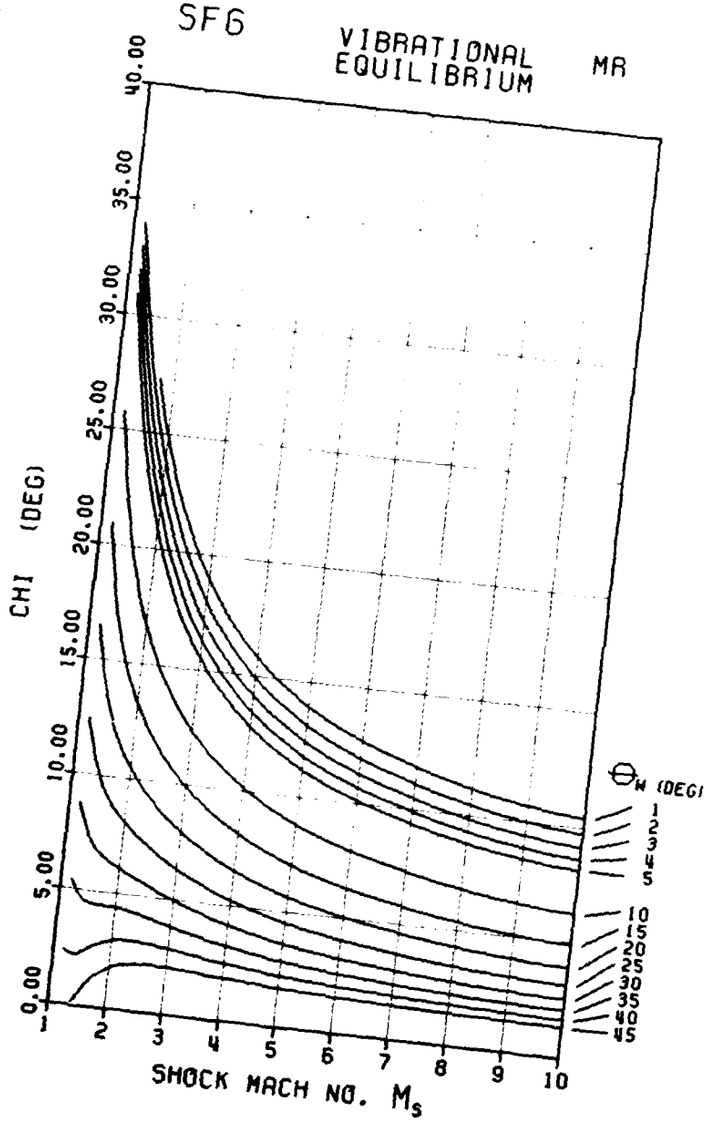

SF6 VIBRATIONAL EQUILIBRIUM MR
PHI1 (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
130.00
115.00
100.00
85.00
70.00
55.00
40.00
25.00
10.00
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 10 15 20 25 30 35 40 45

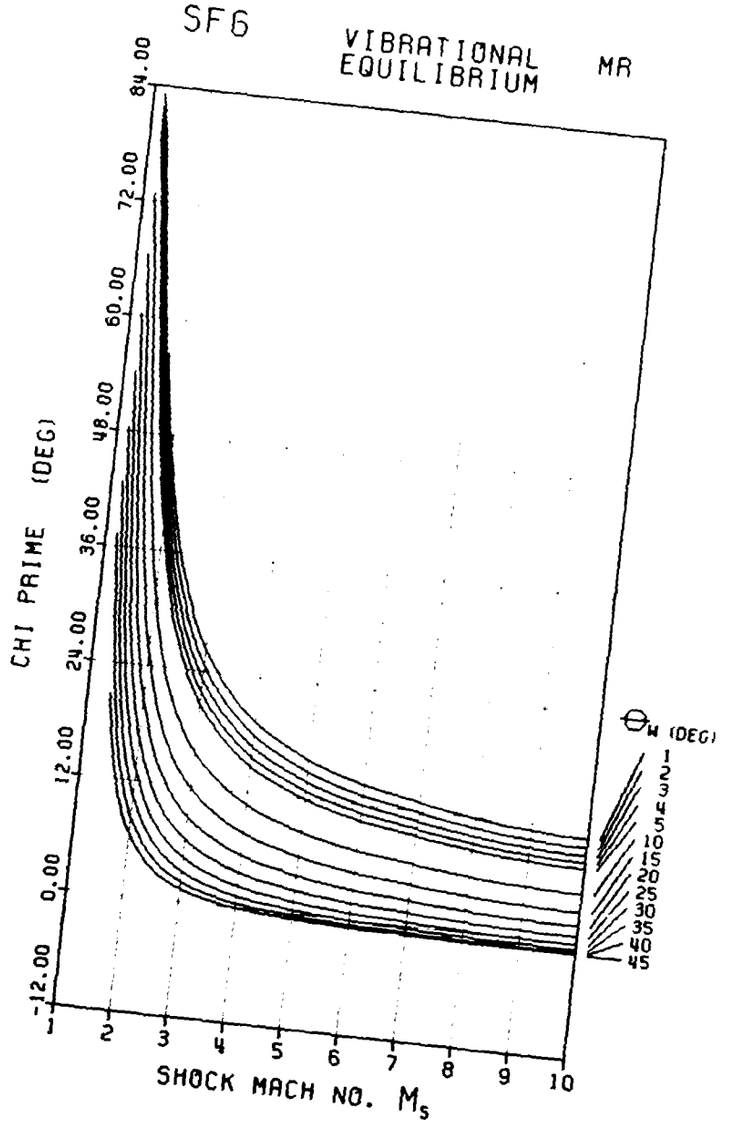

SF6 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
PH13 (DEG)
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

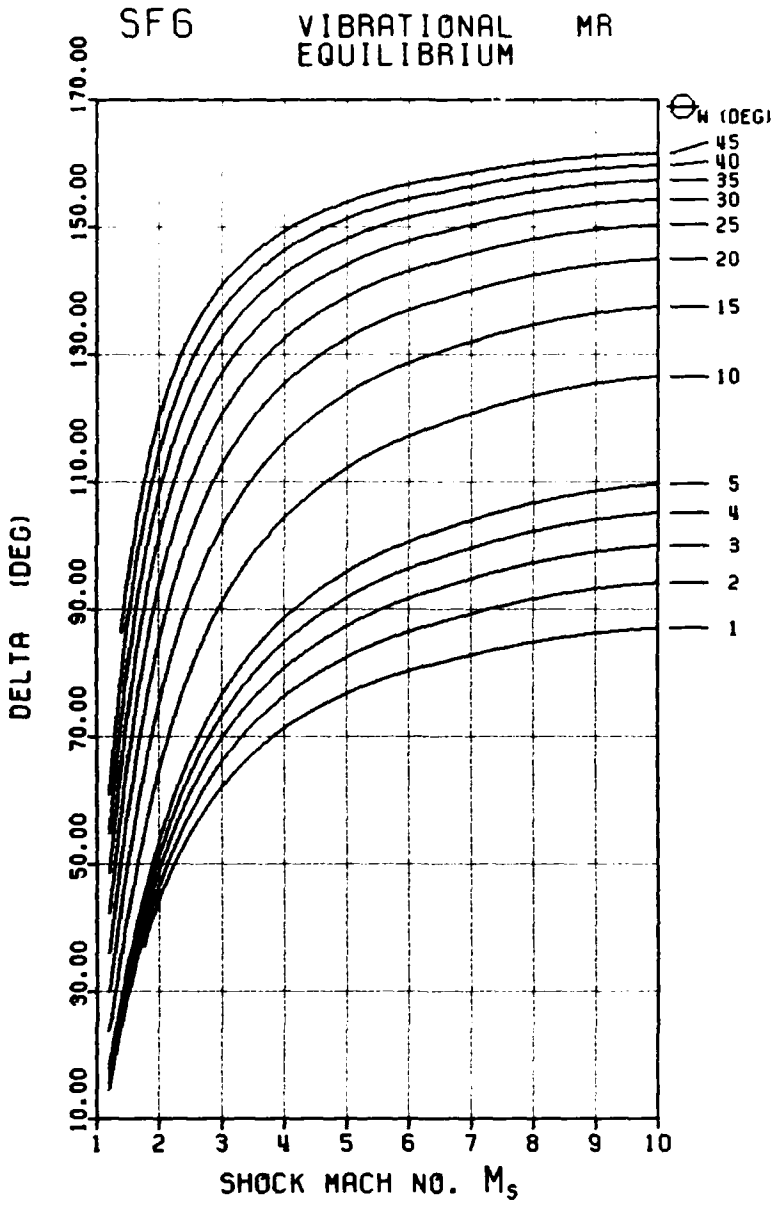

SF6 VIBRATIONAL EQUILIBRIUM MR
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45
THETA1 (DEG)
72.00
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

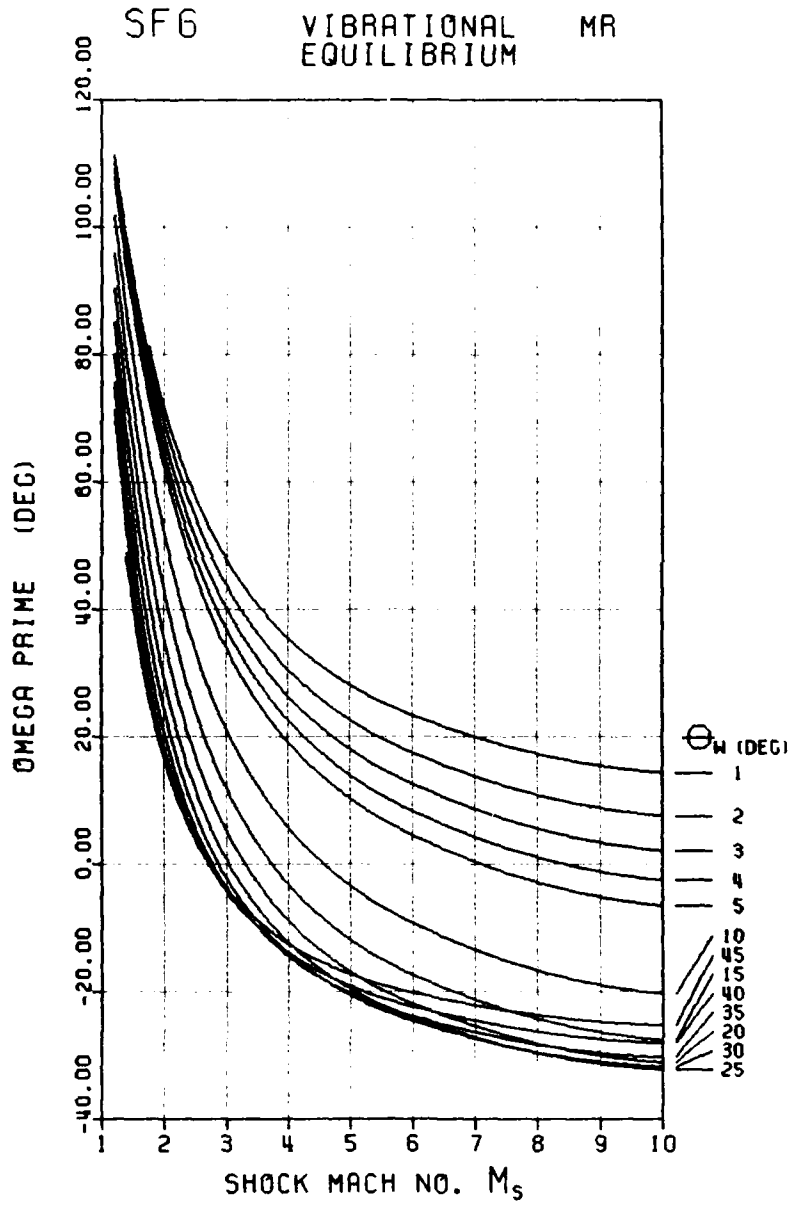

SF6 VIBRATIONAL EQUILIBRIUM MR
THETA2 (DEG)
24.00
20.00
16.00
12.00
8.00
4.00
0.00
-4.00
-8.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1

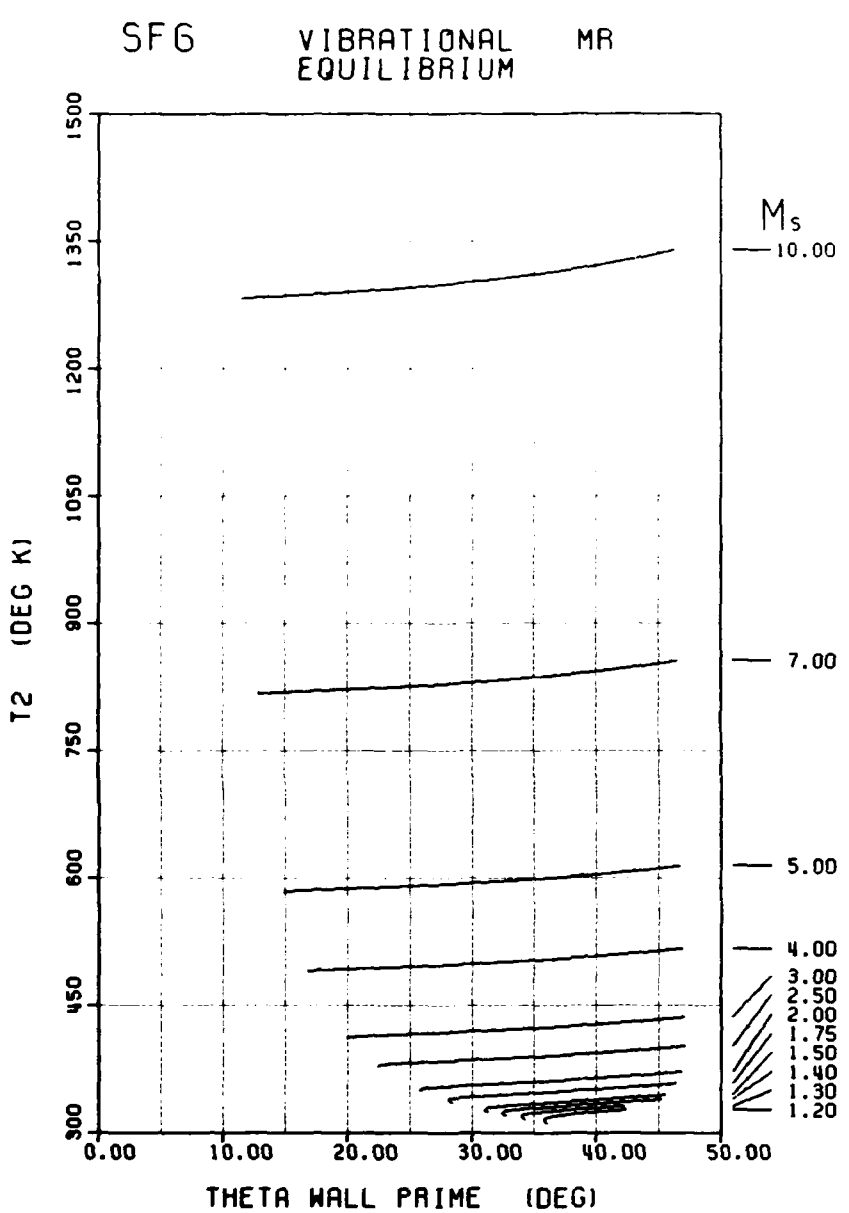

SF6 VIBRATIONAL EQUILIBRIUM MR
THETA3 (DEG)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

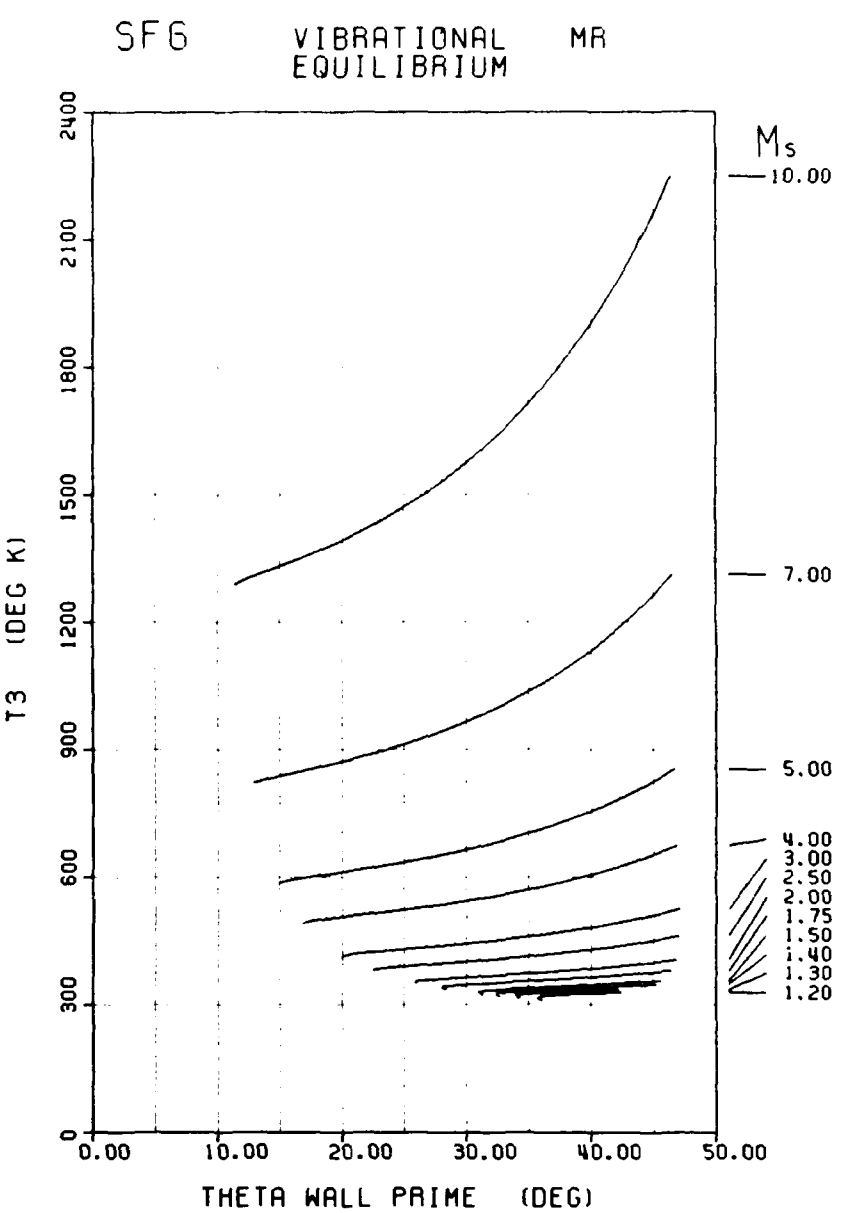

SF6
VIBRATIONAL EQUILIBRIUM
MR
CHI (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

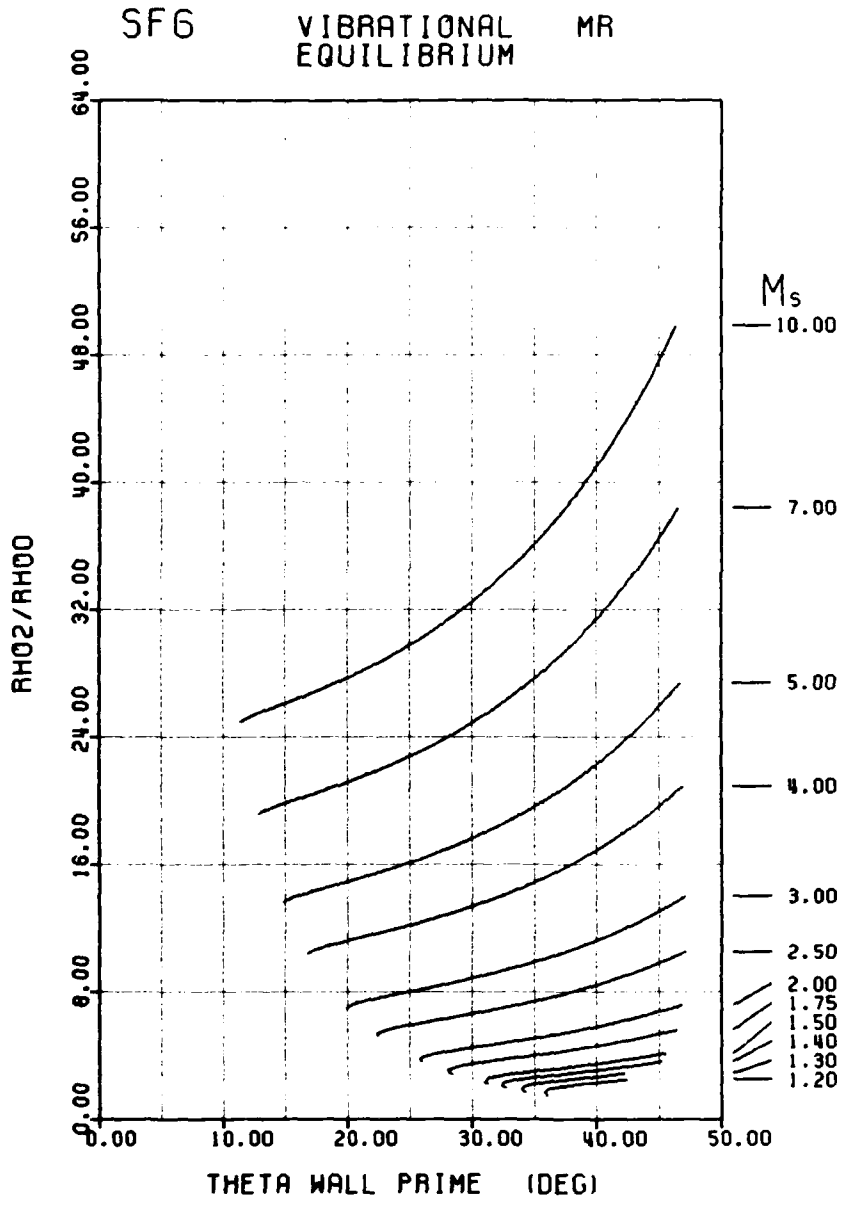

SF6
VIBRATIONAL EQUILIBRIUM
MR
CHI PRIME (DEG)
-12.00
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
1
2
3
4
5
10
15
20
25
30
35
40
45

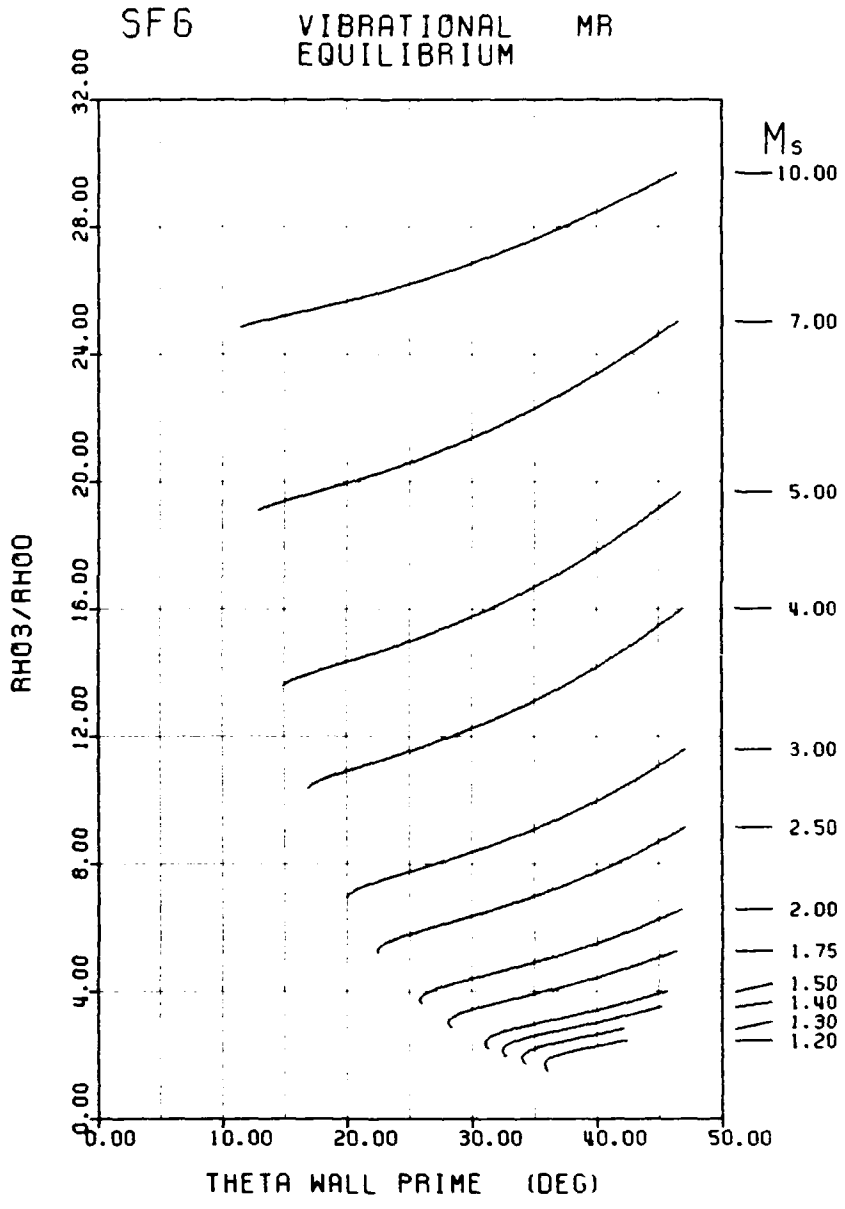

SF6 VIBRATIONAL EQUILIBRIUM MR
DELTA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
40
35
30
25
20
15
10
5
4
3
2
1
170.00
150.00
130.00
110.00
90.00
70.00
50.00
30.00
10.00
1 2 3 4 5 6 7 8 9 10

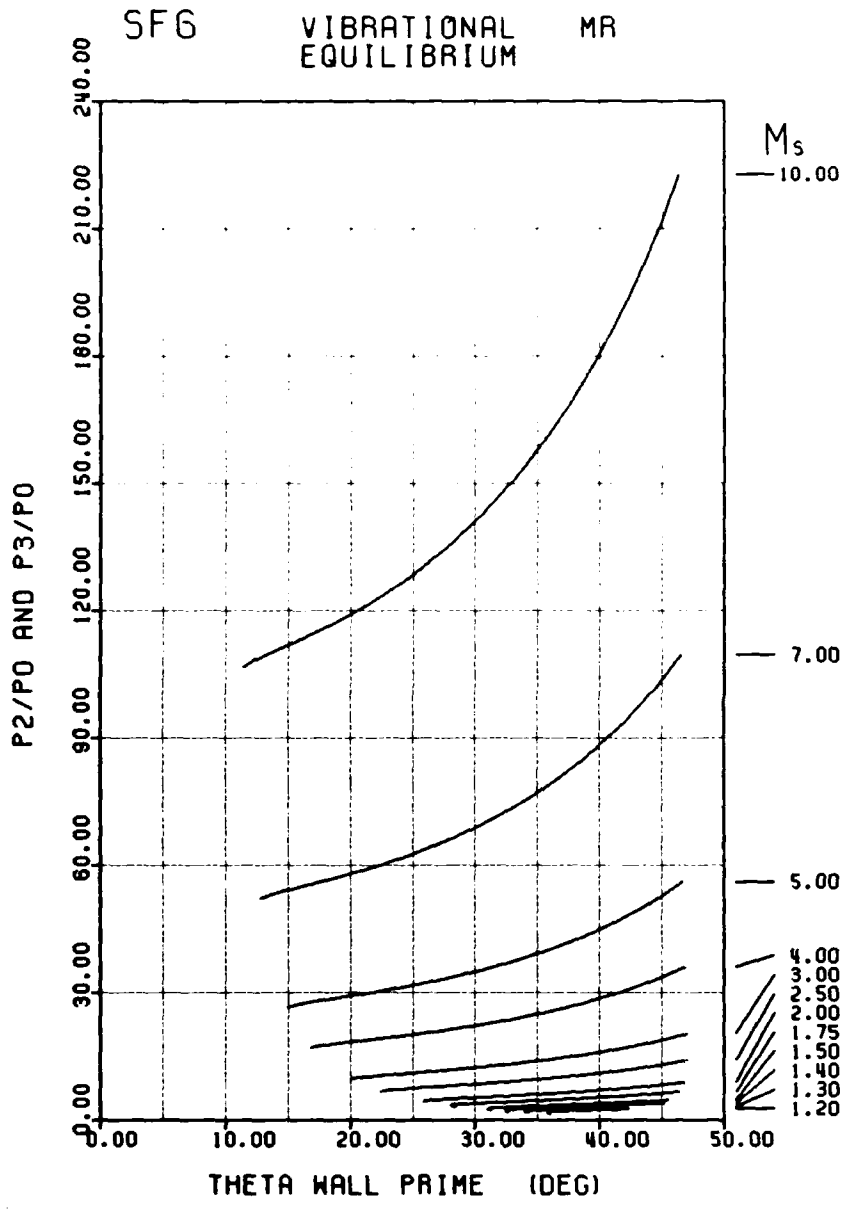

SF6 VIBRATIONAL EQUILIBRIUM MR
OMEGA PRIME (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
1
2
3
4
5
10
45
15
40
35
20
30
25
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
1 2 3 4 5 6 7 8 9 10

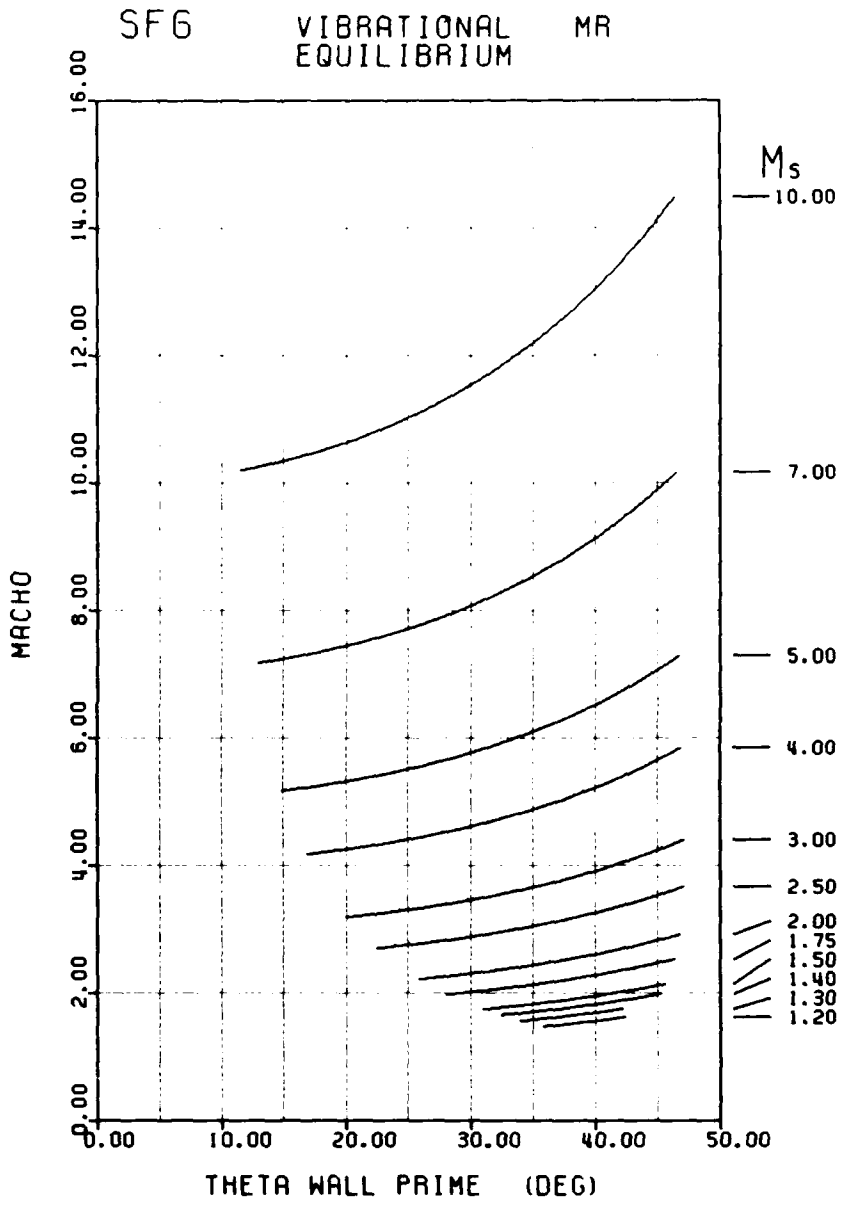

SF6 VIBRATIONAL EQUILIBRIUM MR
T2 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
300
450
600
750
900
1050
1200
1350
1500
0.00
10.00
20.00
30.00
40.00
50.00

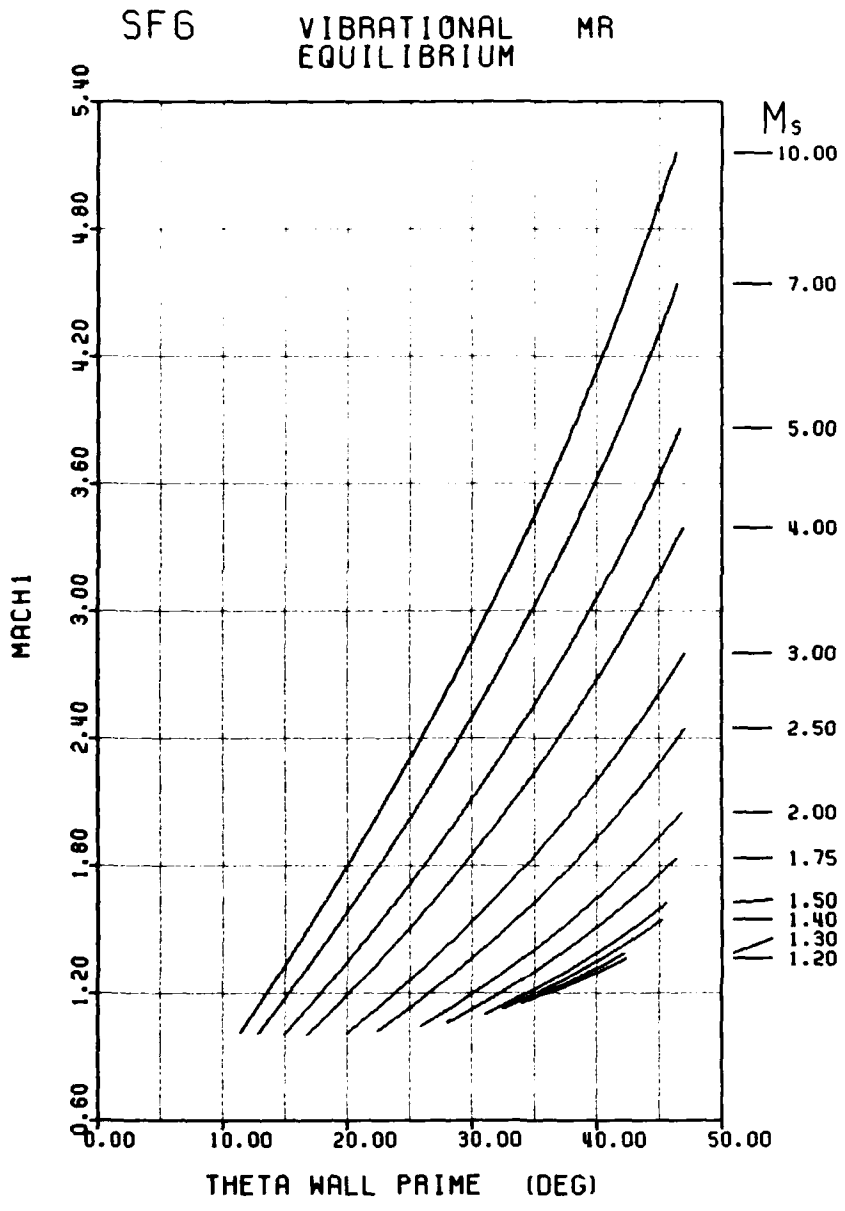

SF6 VIBRATIONAL EQUILIBRIUM MR
T3 (DEG K)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0
300
600
900
1200
1500
1800
2100
2400
0.00
10.00
20.00
30.00
40.00
50.00

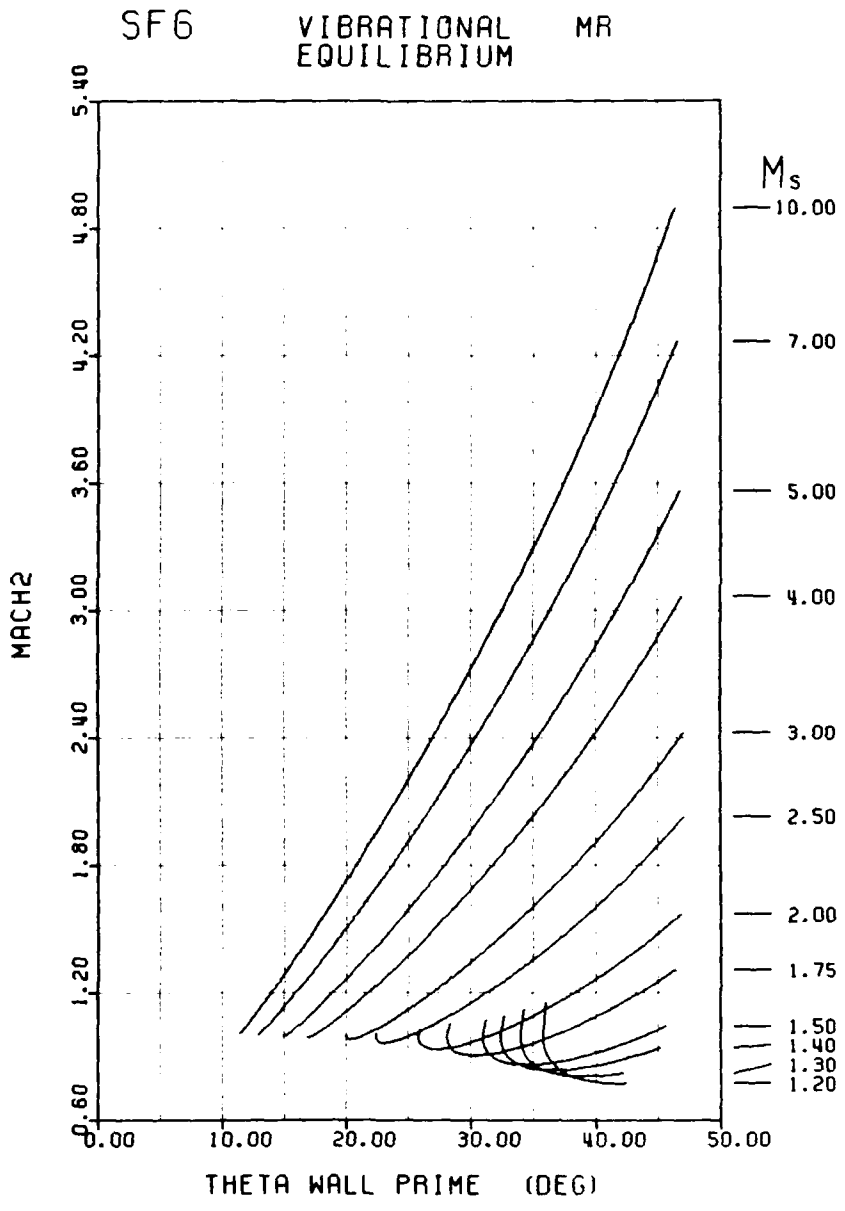

SF6 VIBRATIONAL EQUILIBRIUM MR
RH02/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00
10.00
20.00
30.00
40.00
50.00

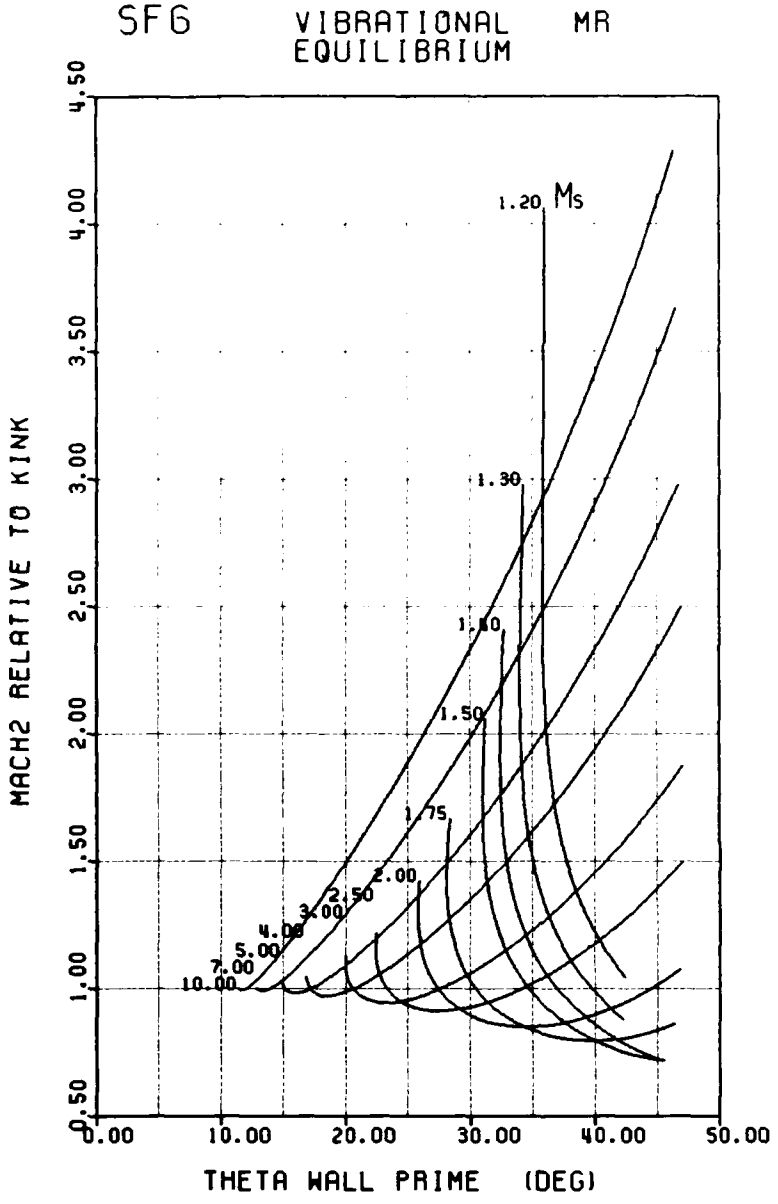

SF6 VIBRATIONAL EQUILIBRIUM MR
RH03/RH00
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
0.00
10.00
20.00
30.00
40.00
50.00

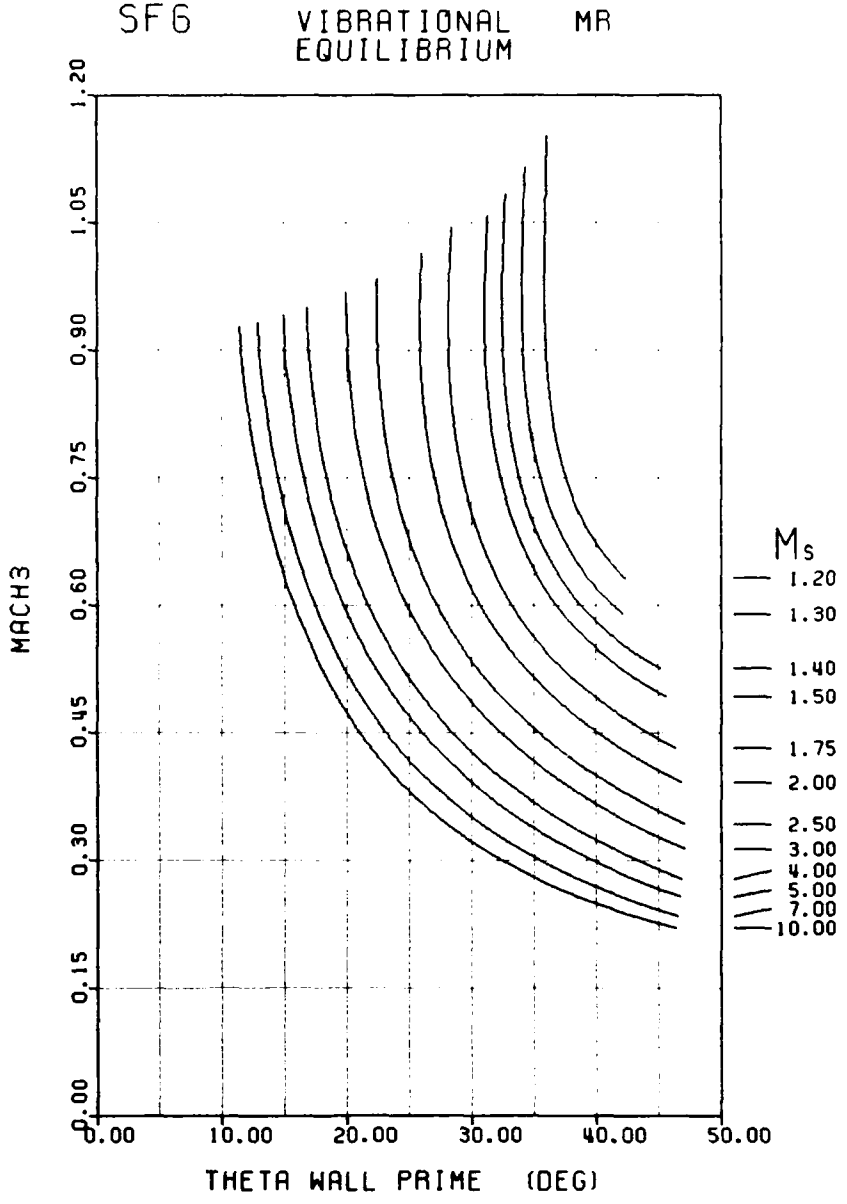

SF6 VIBRATIONAL EQUILIBRIUM MR
P2/PO AND P3/PO
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00
0.00
10.00
20.00
30.00
40.00
50.00

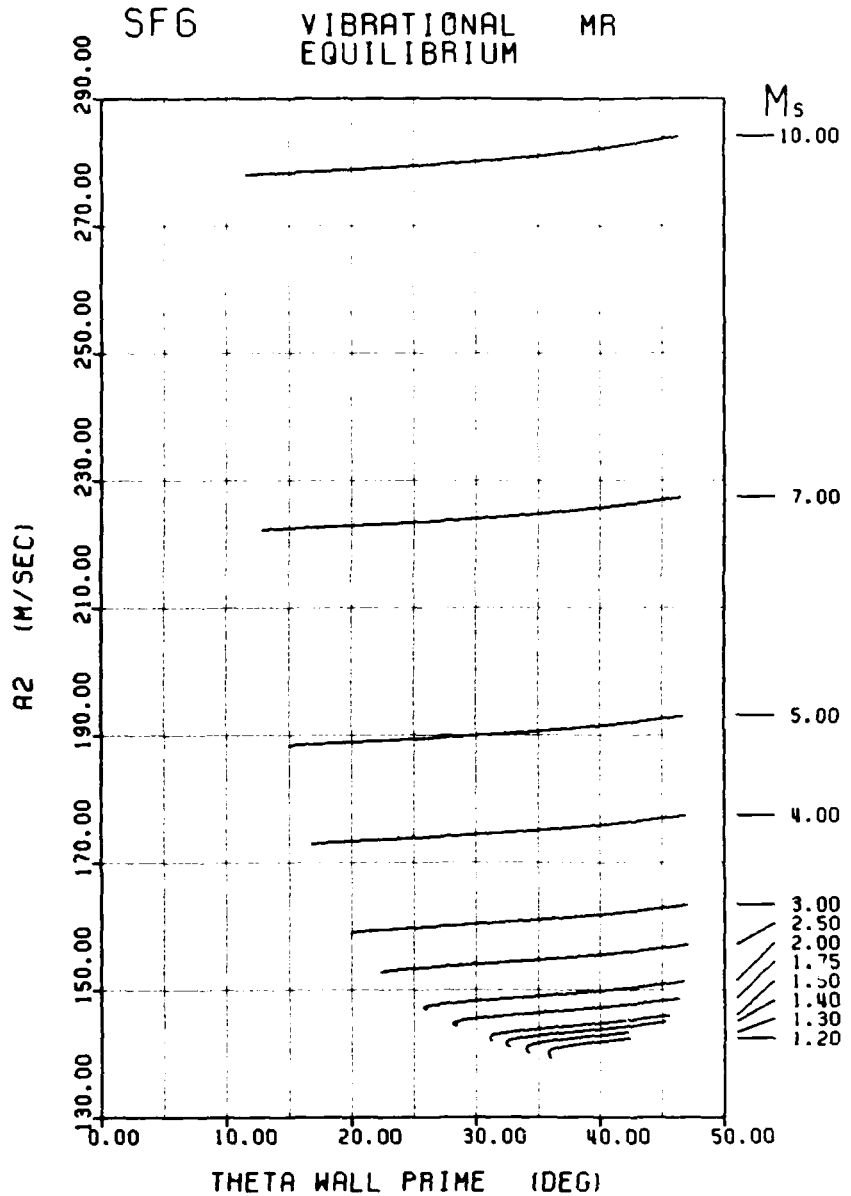

SF6 VIBRATIONAL EQUILIBRIUM MR
MACHO
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
0.00
10.00
20.00
30.00
40.00
50.00

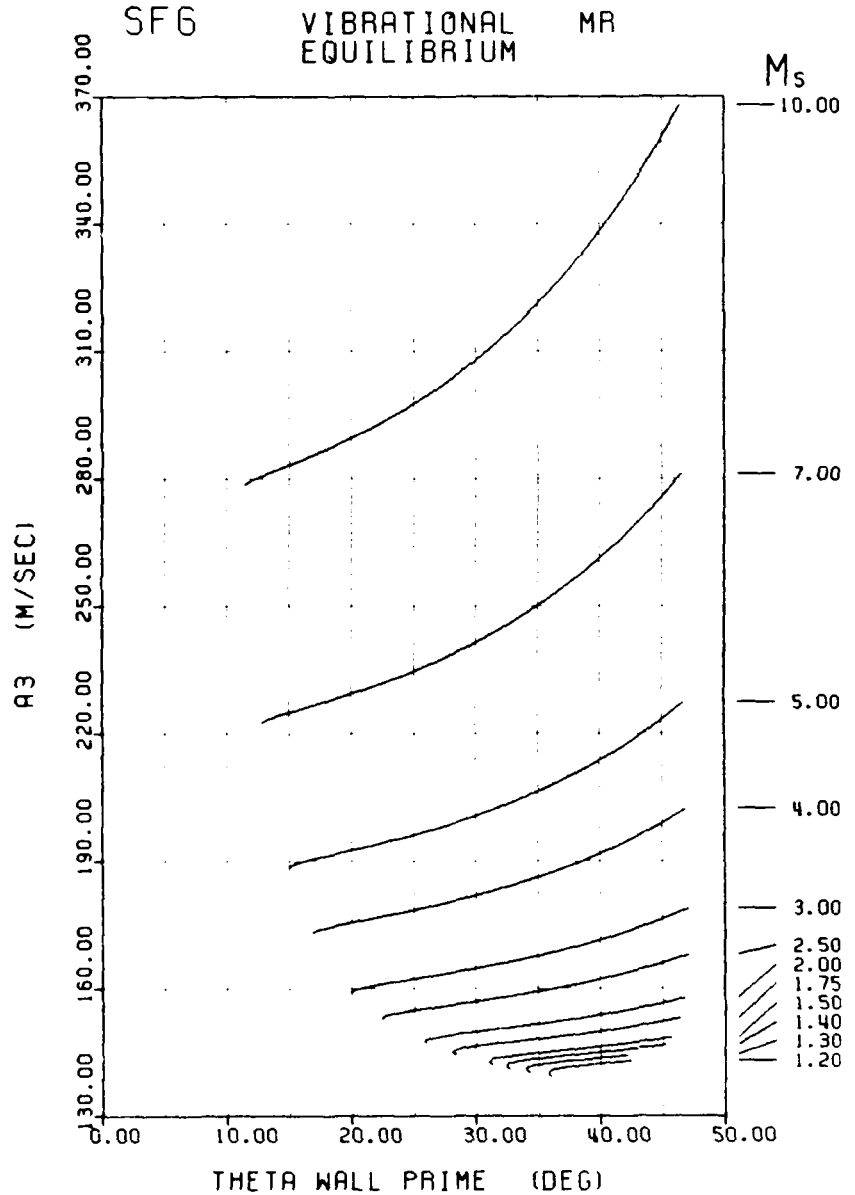

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH1
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.60
1.20
1.80
2.40
3.00
3.60
4.20
4.80
5.40
0.00
10.00
20.00
30.00
40.00
50.00

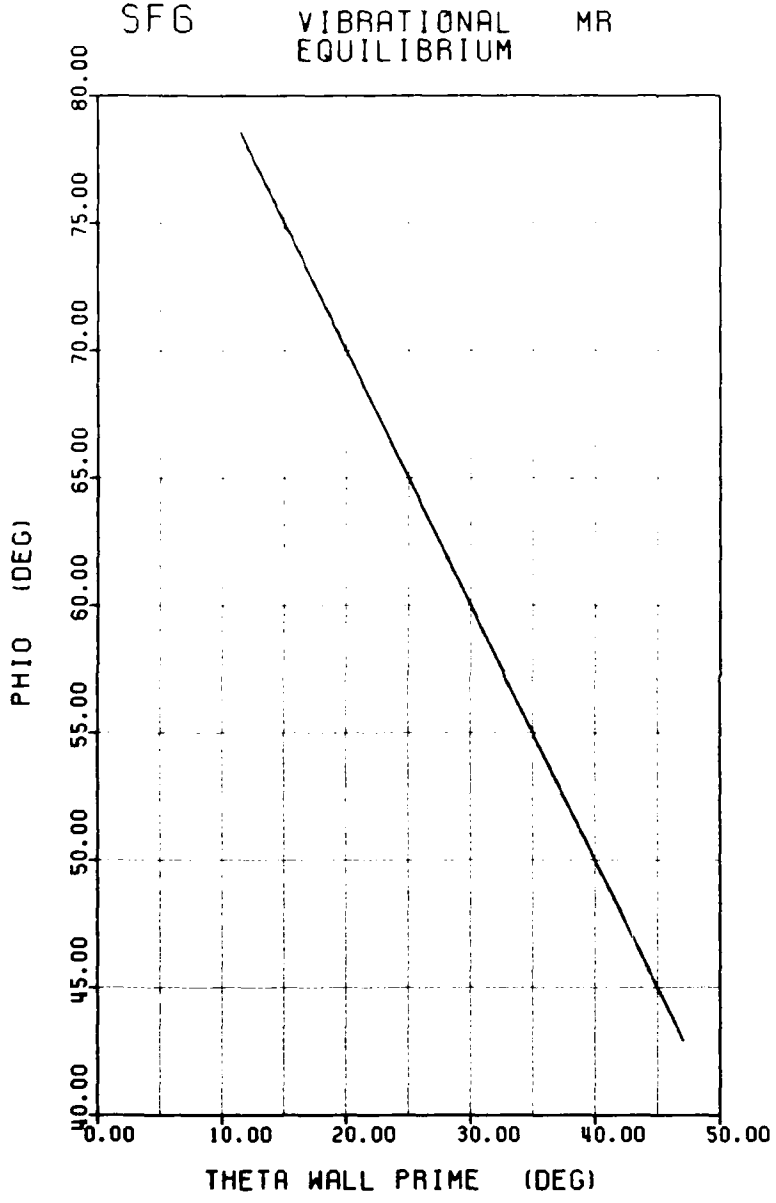

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH2
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
0.60
1.20
1.80
2.40
3.00
3.60
4.20
4.80
5.40
0.00
10.00
20.00
30.00
40.00
50.00

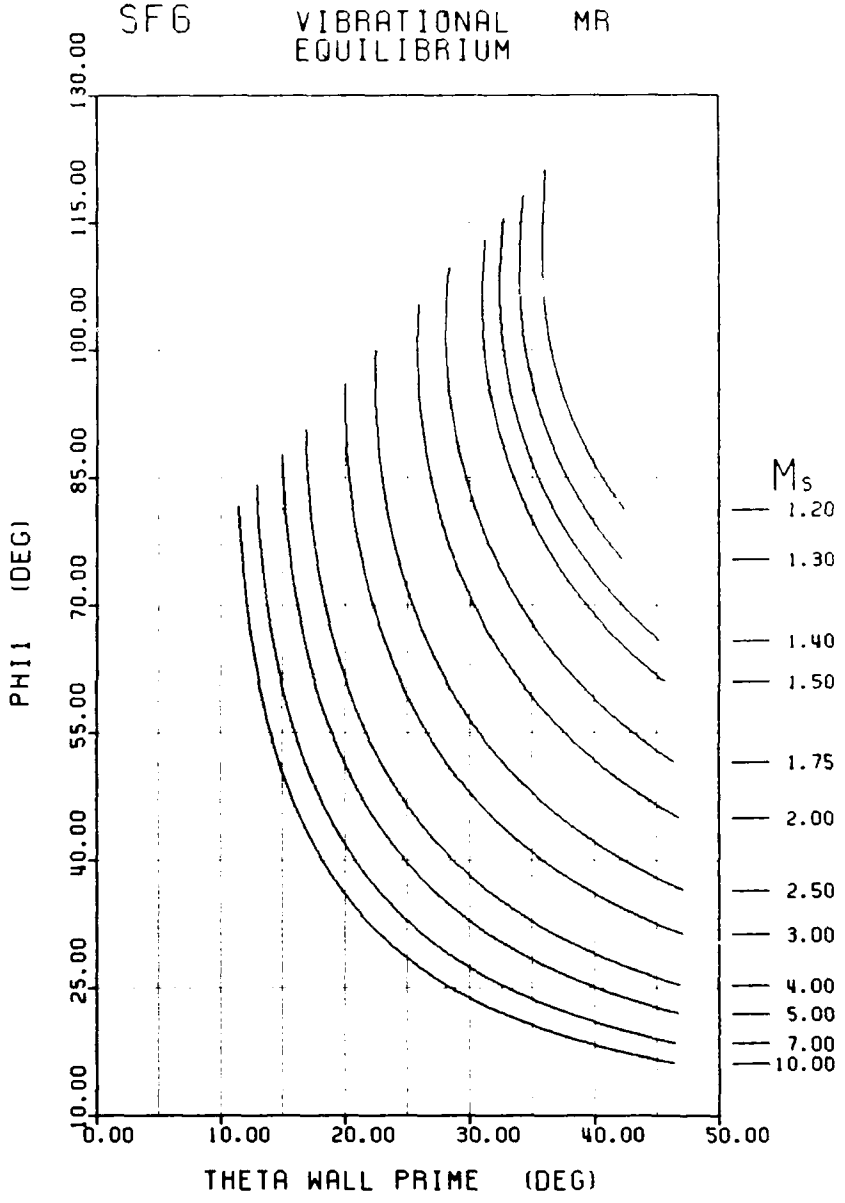

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH2 RELATIVE TO KINK
THETA WALL PRIME (DEG)
1.20 Ms
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

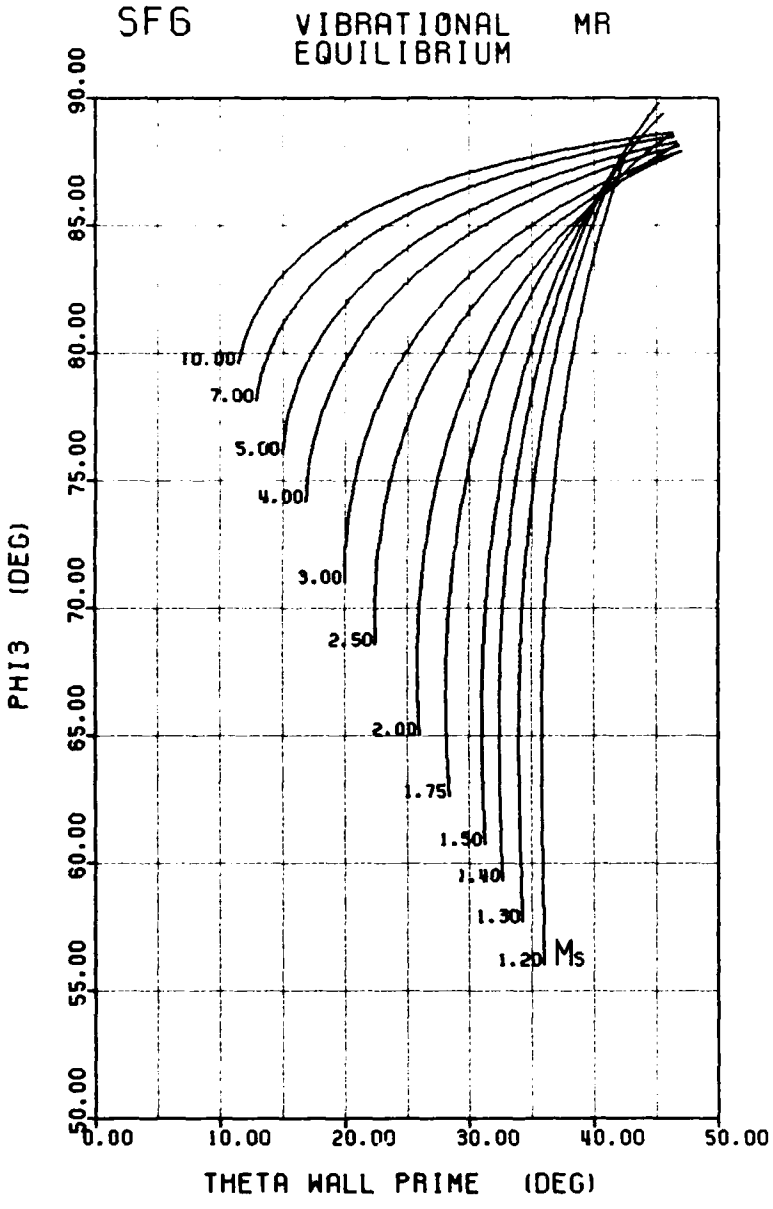

SF6 VIBRATIONAL EQUILIBRIUM MR
MACH3
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

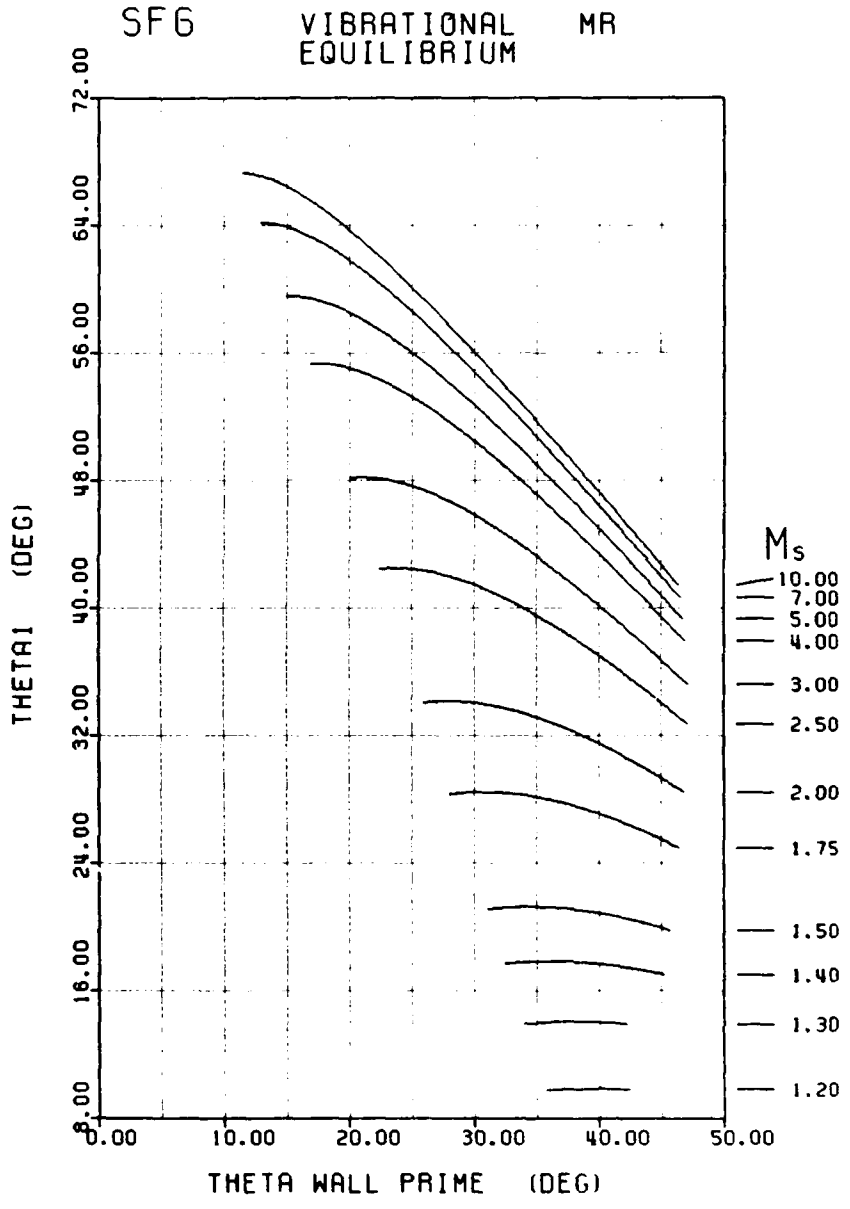

SF6 VIBRATIONAL EQUILIBRIUM MR
A2 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
290.00
270.00
250.00
230.00
210.00
190.00
170.00
150.00
130.00
0.00
10.00
20.00
30.00
40.00
50.00

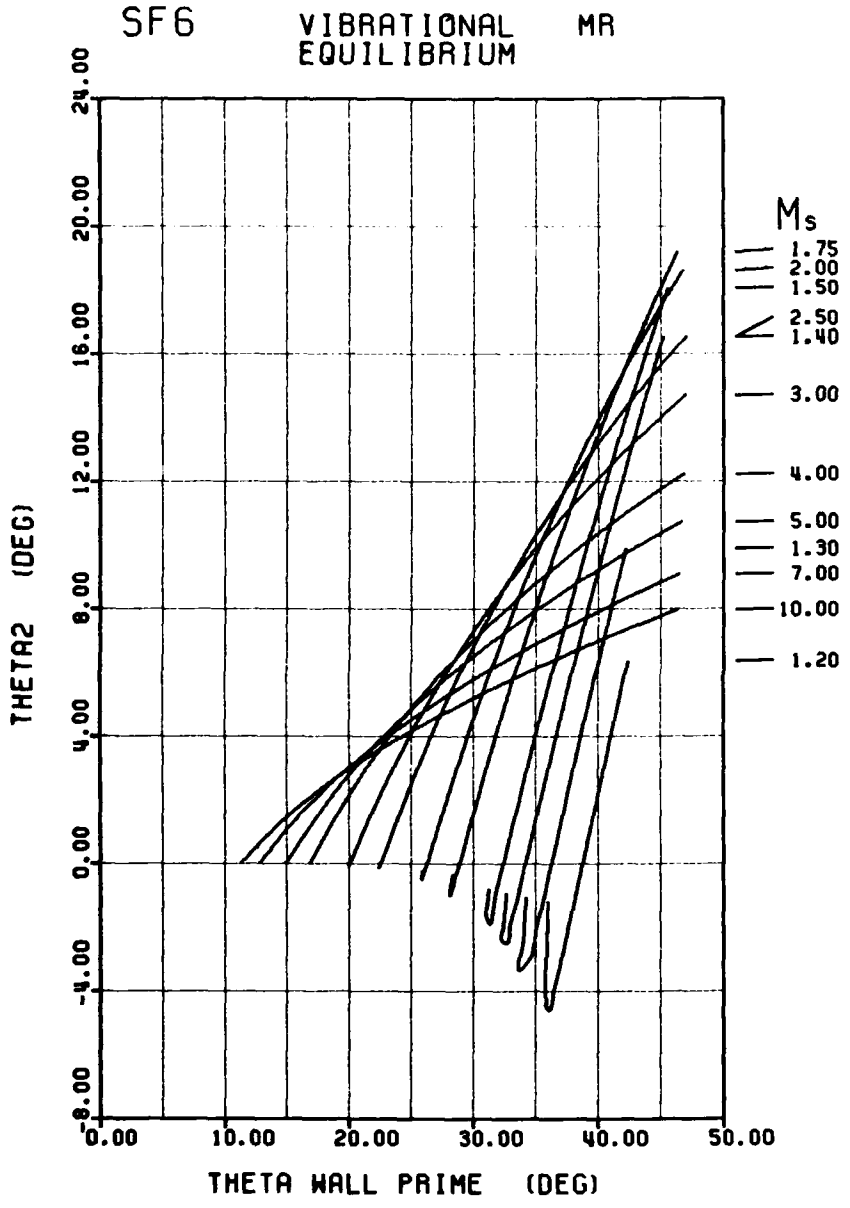

SF6 VIBRATIONAL EQUILIBRIUM MR
A3 (M/SEC)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
370.00
340.00
310.00
280.00
250.00
220.00
190.00
160.00
130.00
0.00
10.00
20.00
30.00
40.00
50.00

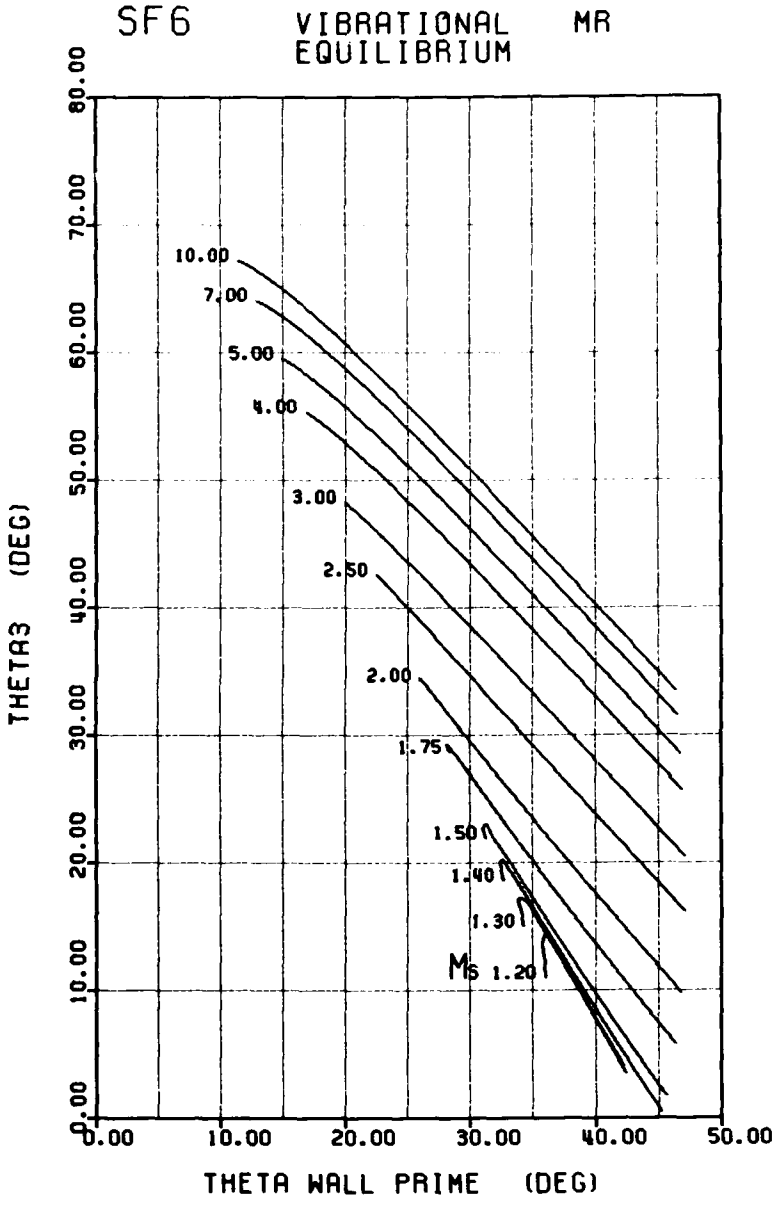

SF6 VIBRATIONAL EQUILIBRIUM MR
PHI0 (DEG)
80.00
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
0.00
10.00
20.00
30.00
40.00
50.00
THETA WALL PRIME (DEG)

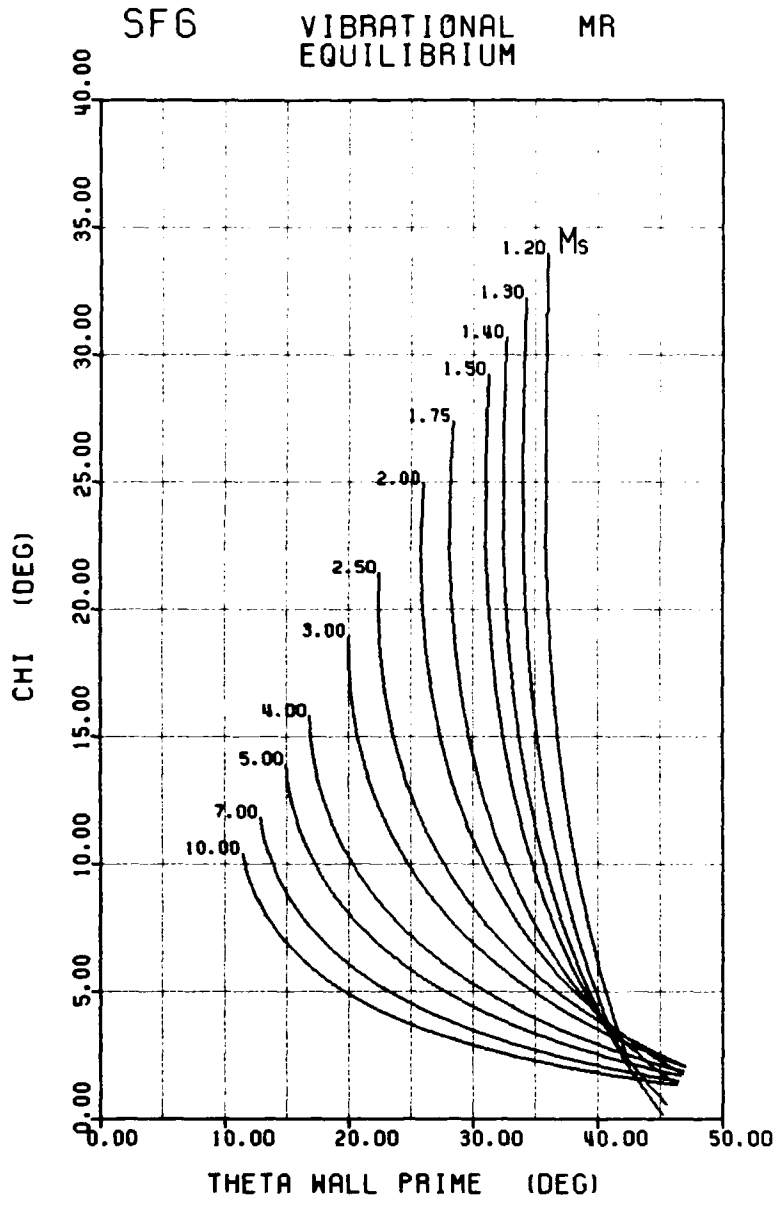

SF6 VIBRATIONAL EQUILIBRIUM MR
PHI1 (DEG)
130.00
115.00
100.00
85.00
70.00
55.00
40.00
25.00
10.00
0.00
10.00
20.00
30.00
40.00
50.00
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00

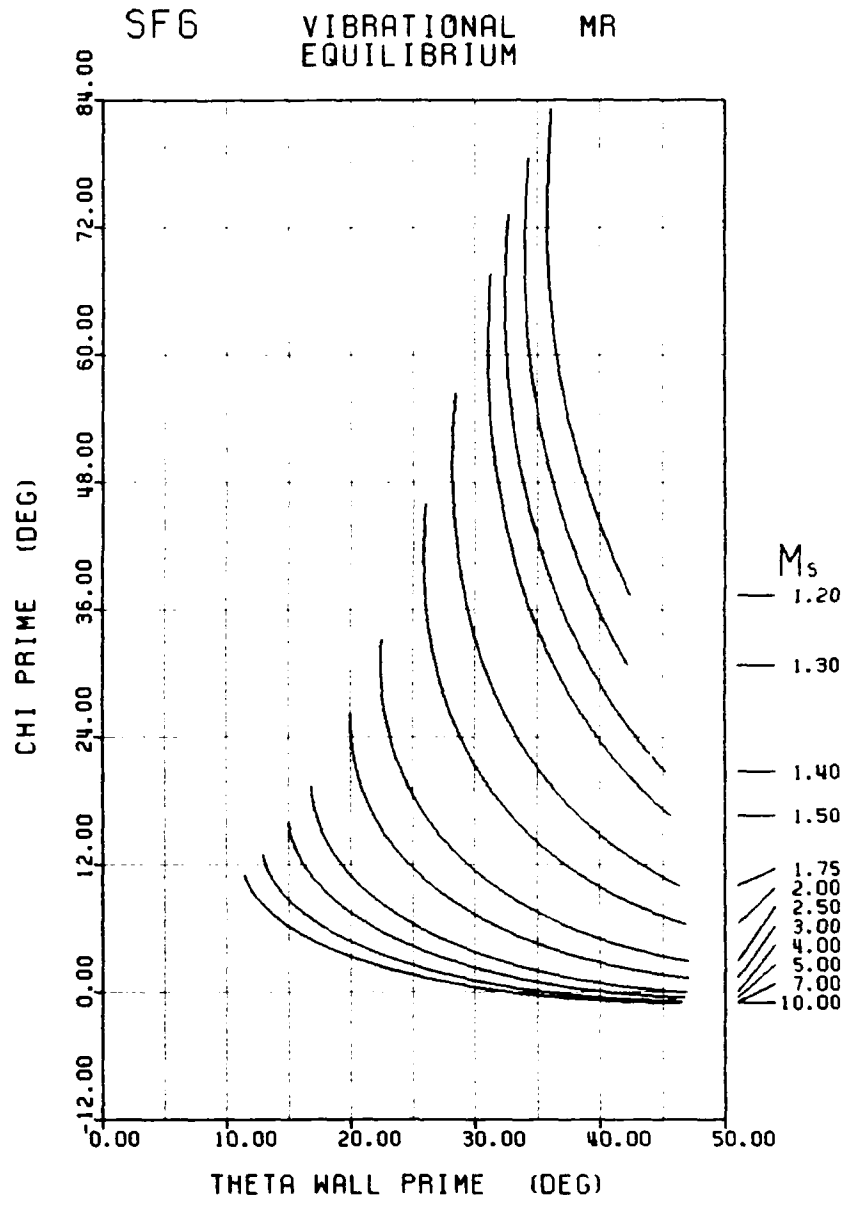

SF6 VIBRATIONAL EQUILIBRIUM MR
PHI3 (DEG)
THETA WALL PRIME (DEG)
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
0.00
10.00
20.00
30.00
40.00
50.00
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
Ms

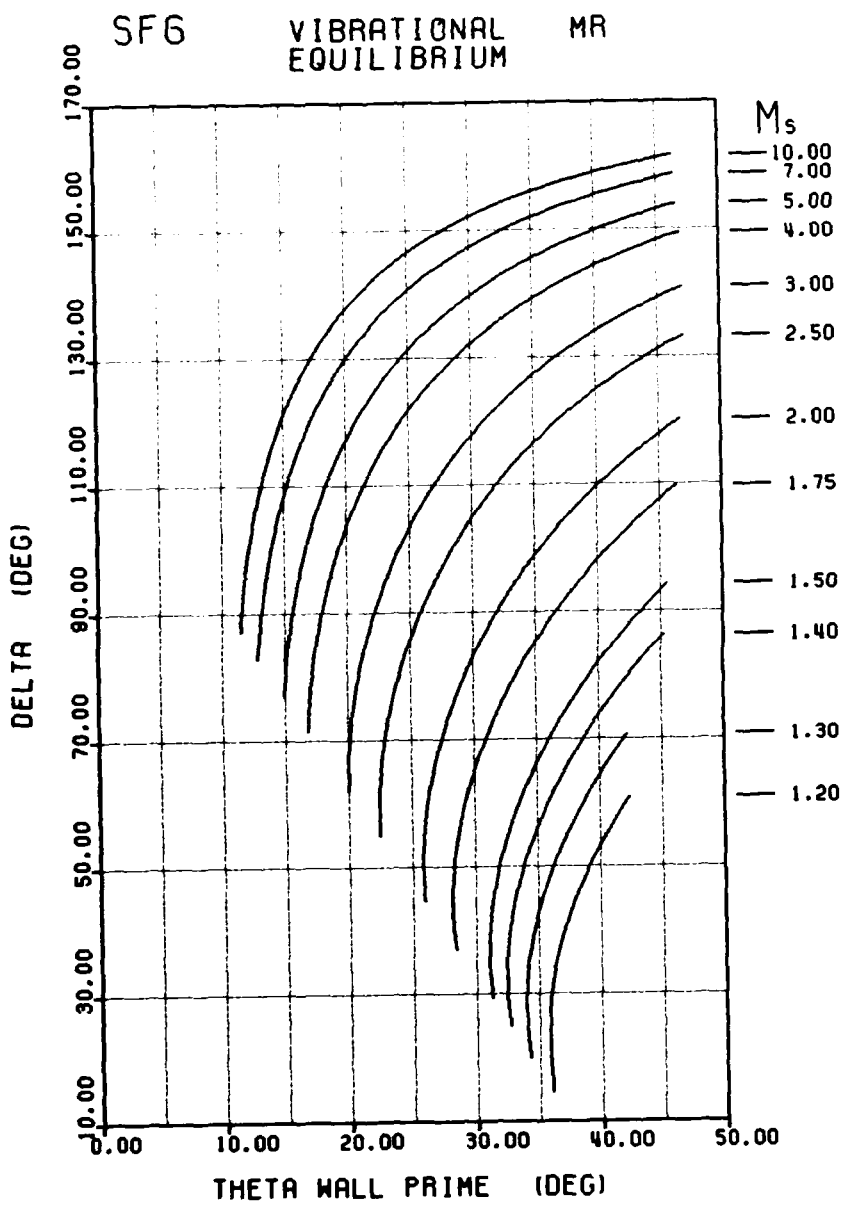

SF6 VIBRATIONAL EQUILIBRIUM MR
THETA1 (DEG)
THETA WALL PRIME (DEG)
72.00
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
10.00
20.00
30.00
40.00
50.00
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20

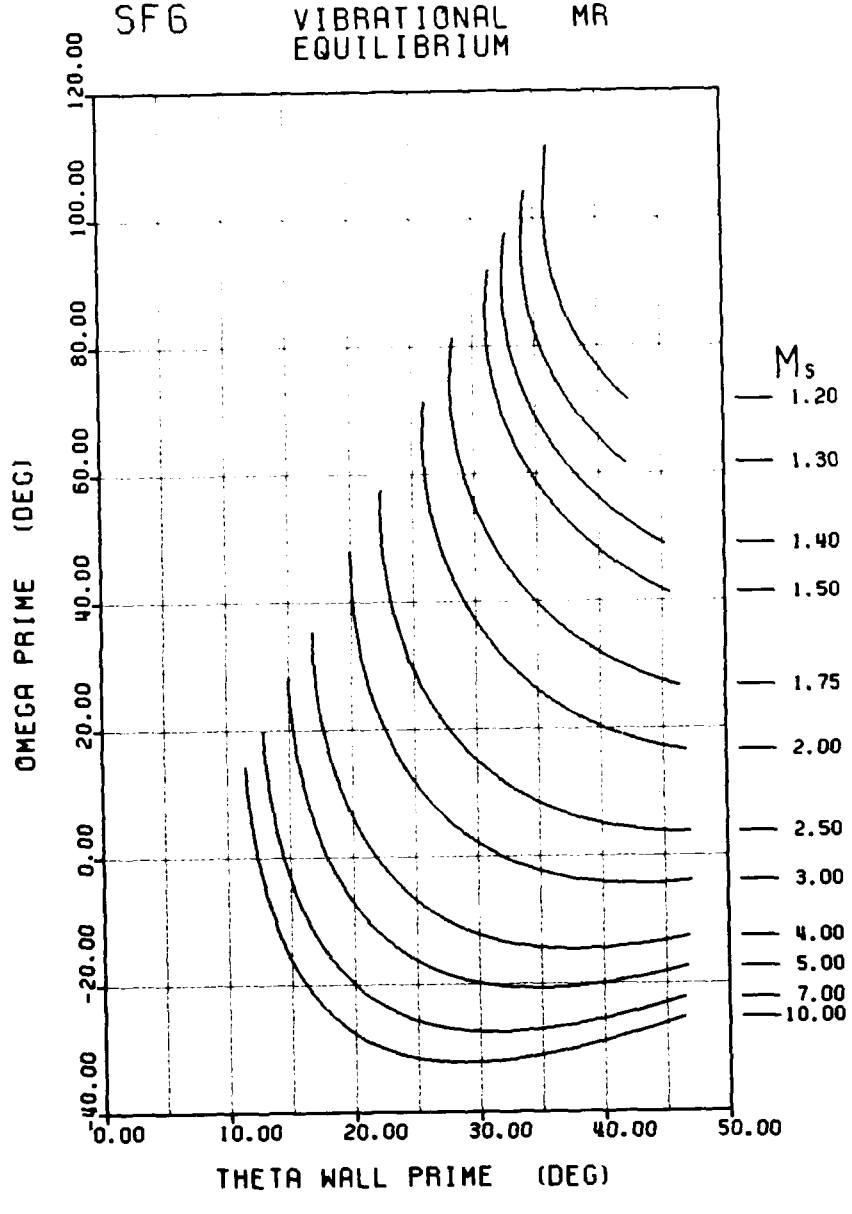

SF6 VIBRATIONAL EQUILIBRIUM MR
THETA2 (DEG)
THETA WALL PRIME (DEG)
Ms
1.75
2.00
1.50
2.50
1.40
3.00
4.00
5.00
1.30
7.00
10.00
1.20
24.00
20.00
16.00
12.00
8.00
4.00
0.00
-4.00
-8.00
0.00
10.00
20.00
30.00
40.00
50.00

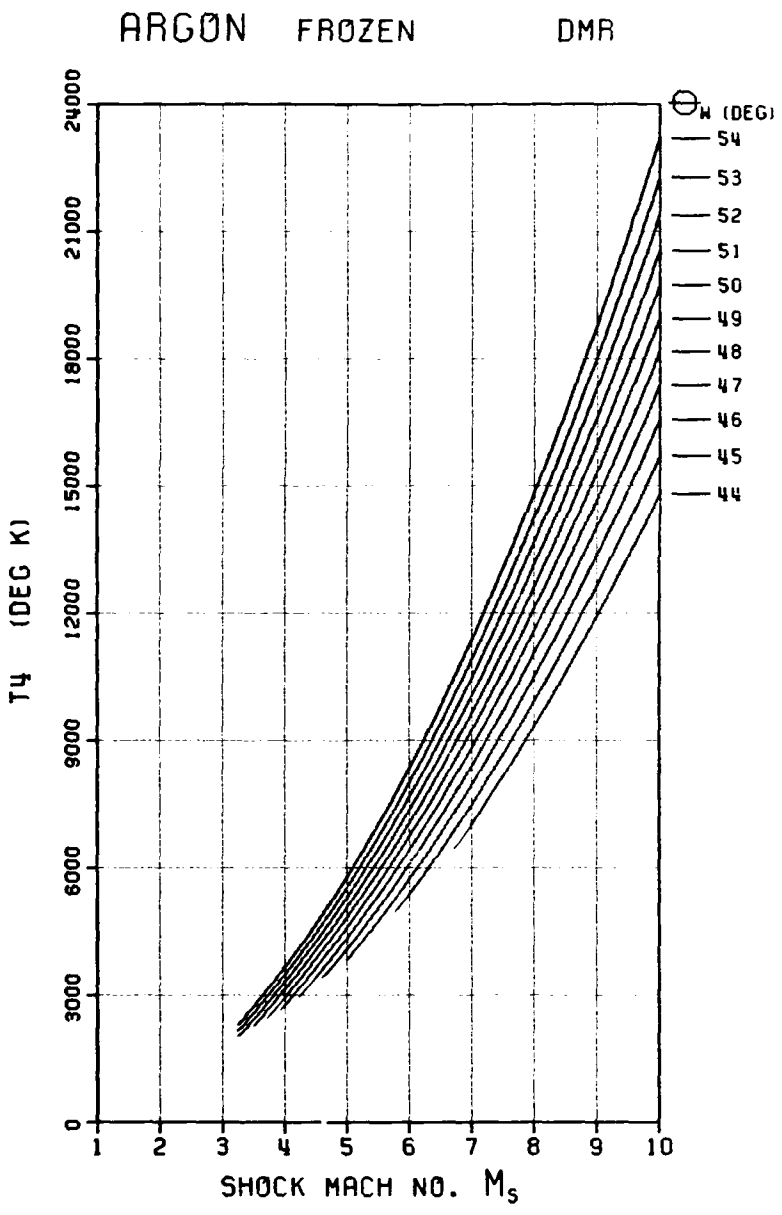

SF6 VIBRATIONAL EQUILIBRIUM MR
THETA3 (DEG)
THETA WALL PRIME (DEG)
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
Ms 1.20
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00

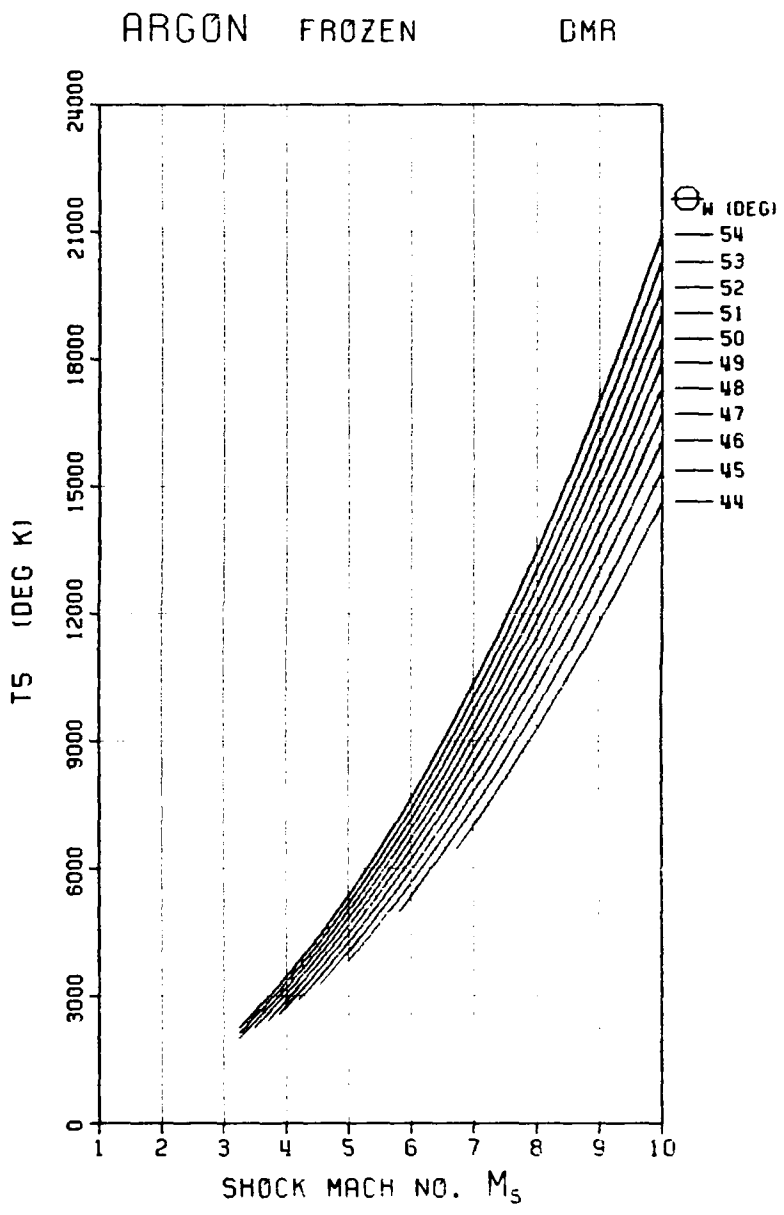

SF6 VIBRATIONAL EQUILIBRIUM MR
CHI (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
0.00
10.00
20.00
30.00
40.00
50.00

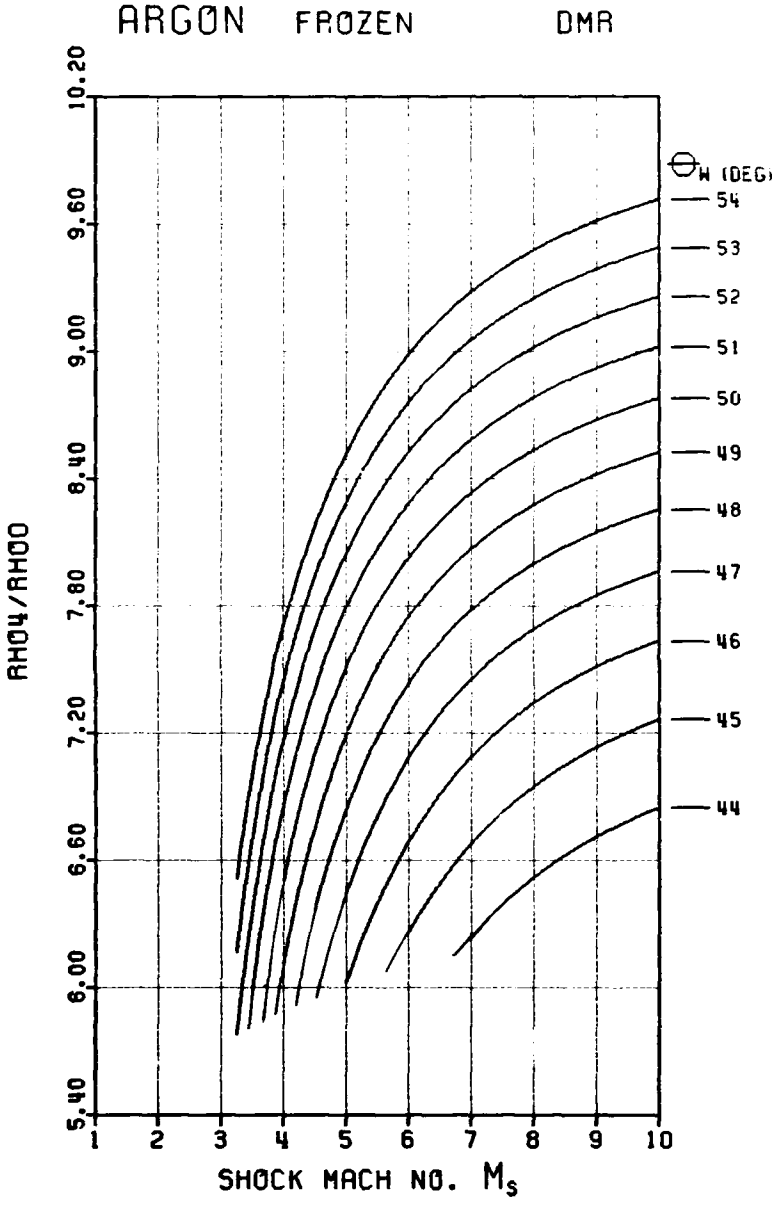

SF6 VIBRATIONAL EQUILIBRIUM MR
CHI PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
-12.00
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
0.00
10.00
20.00
30.00
40.00
50.00

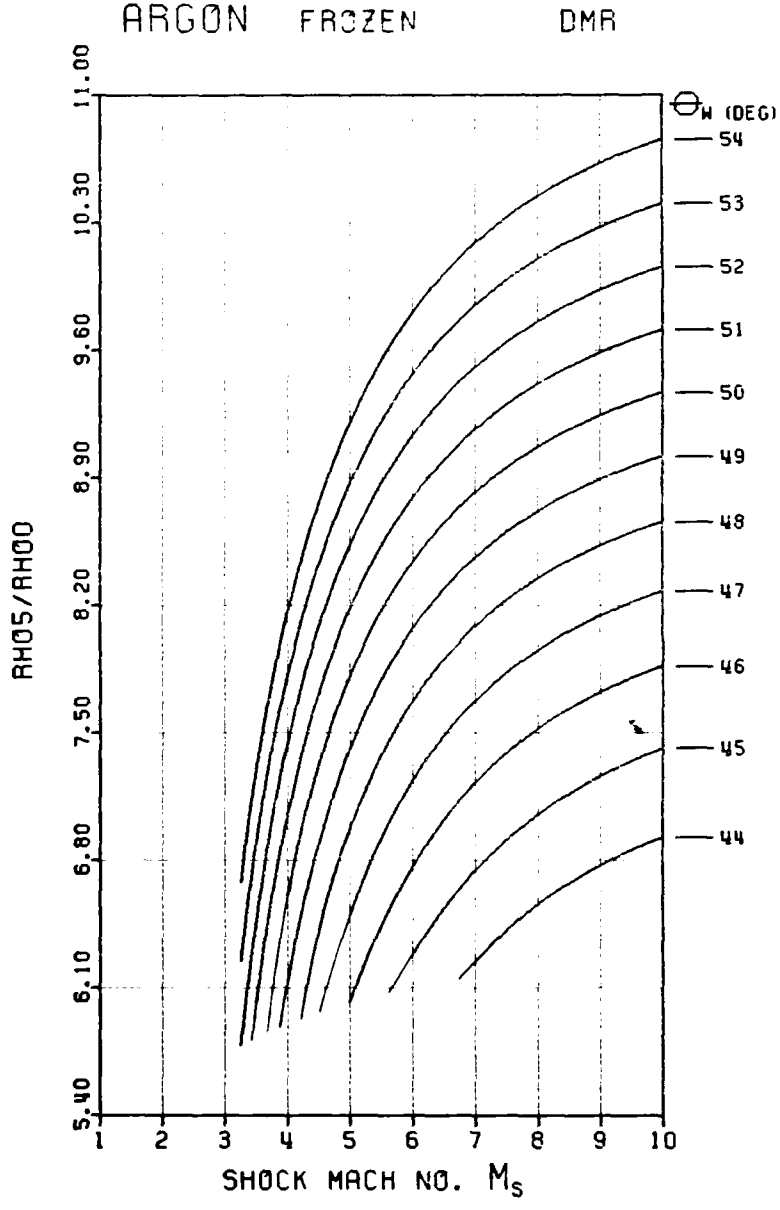

SF6 VIBRATIONAL EQUILIBRIUM MR
DELTA (DEG)
THETA WALL PRIME (DEG)
Ms
10.00
7.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.40
1.30
1.20
10.00
30.00
50.00
70.00
90.00
110.00
130.00
150.00
170.00
0.00
10.00
20.00
30.00
40.00
50.00

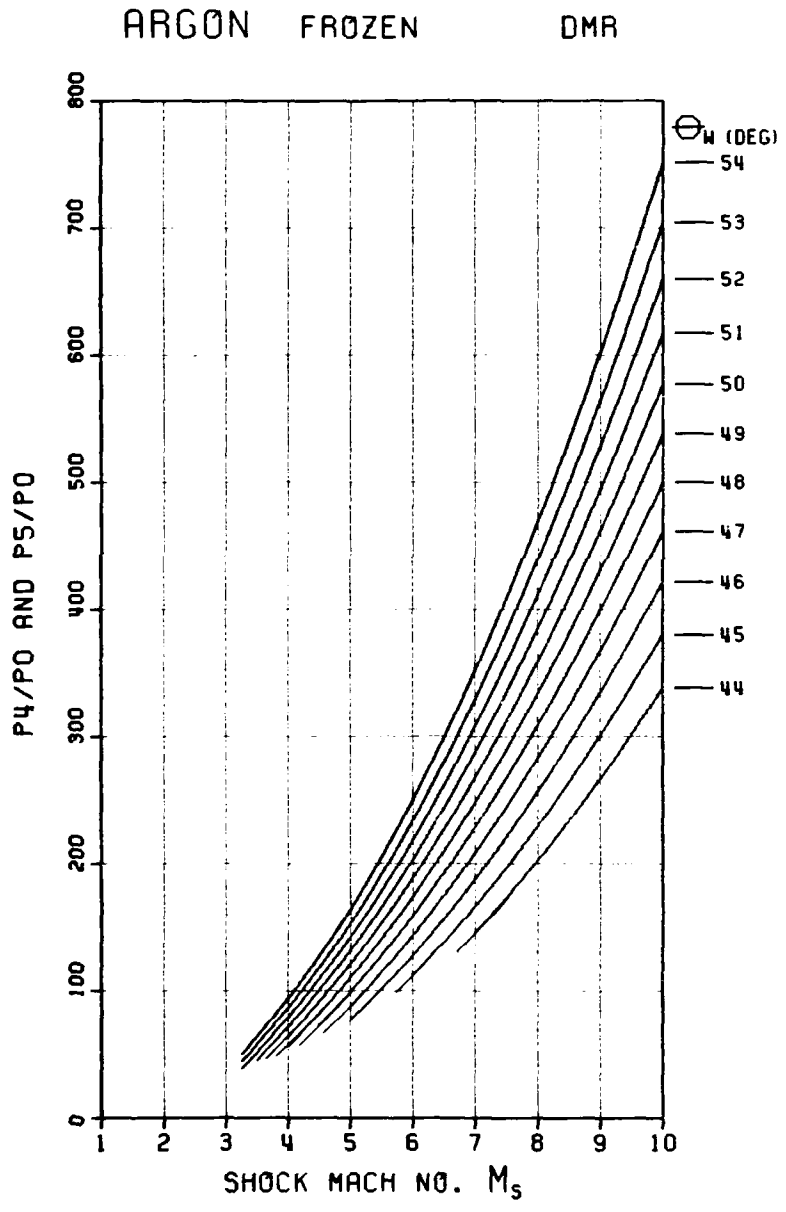

SF6 VIBRATIONAL EQUILIBRIUM MR
OMEGA PRIME (DEG)
THETA WALL PRIME (DEG)
Ms
1.20
1.30
1.40
1.50
1.75
2.00
2.50
3.00
4.00
5.00
7.00
10.00
-40.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.00
10.00
20.00
30.00
40.00
50.00

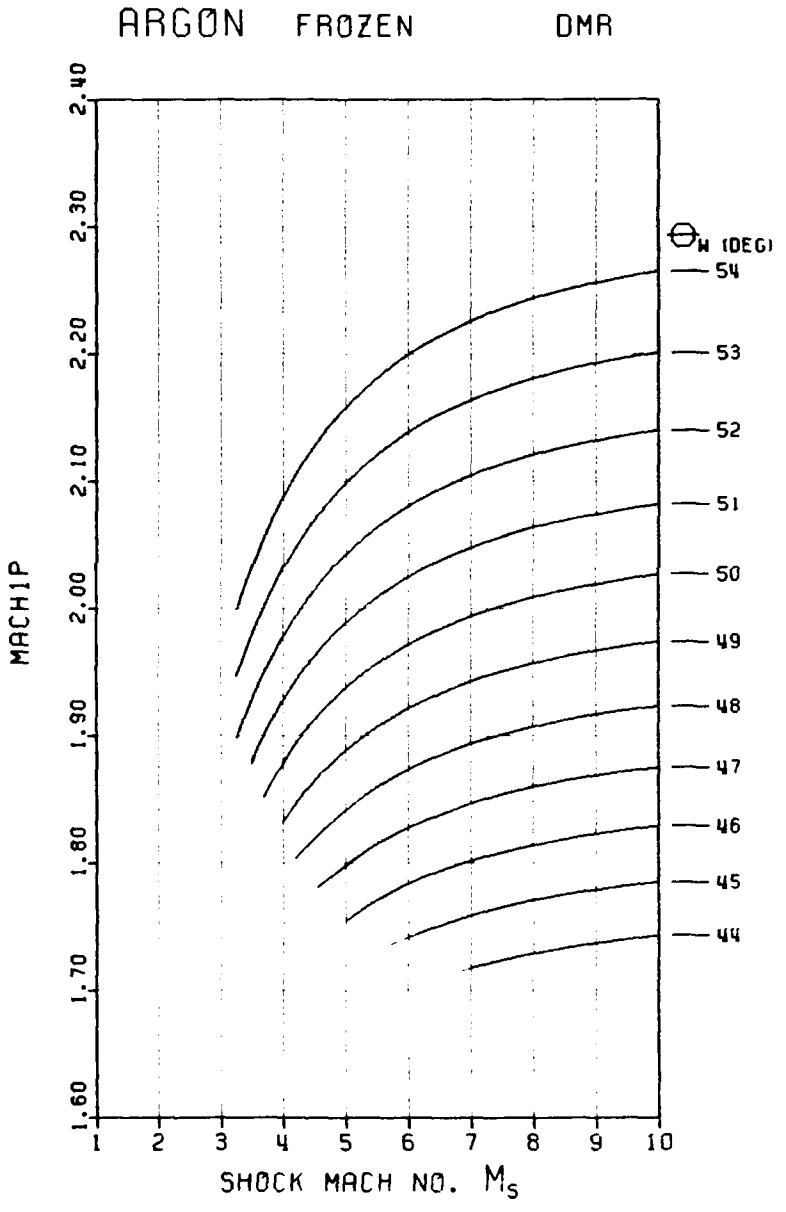

ARGON FROZEN DMR
T4 (DEG K)
0
3000
6000
9000
12000
15000
18000
21000
24000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

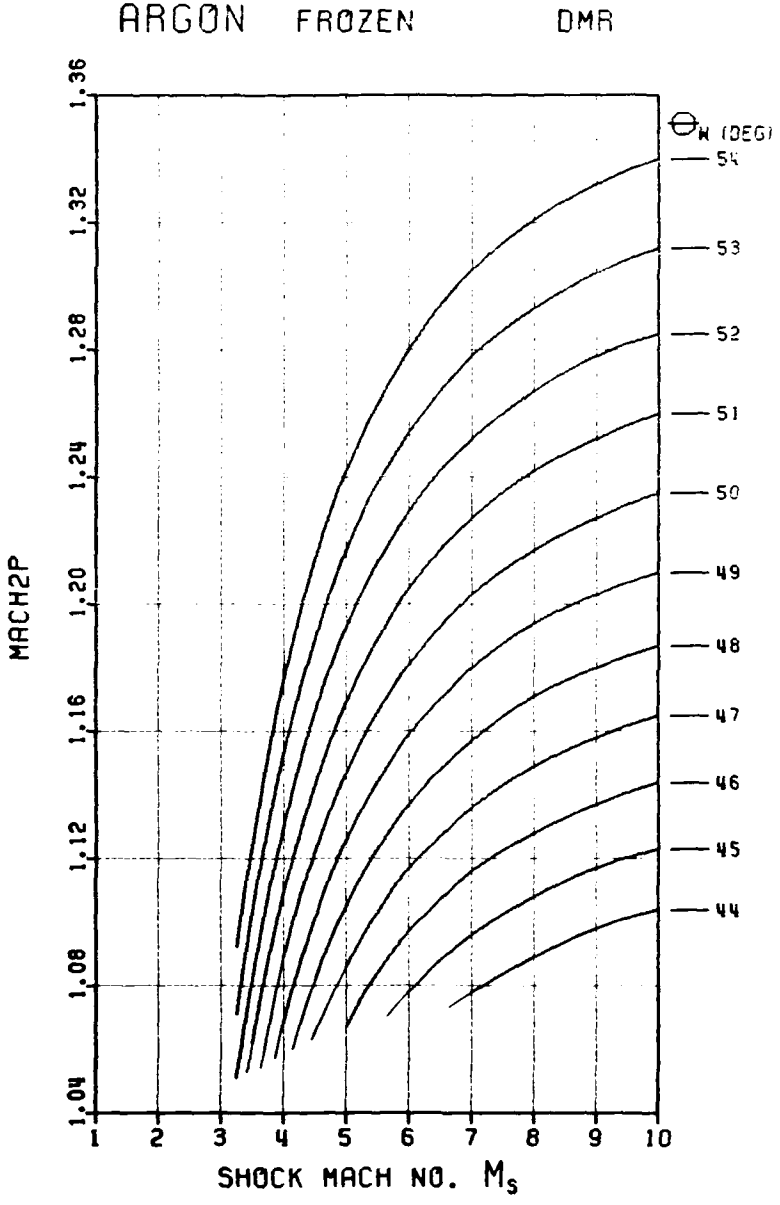

ARGON FROZEN DMR
T5 (DEG K)
0
3000
6000
9000
12000
15000
18000
21000
24000
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

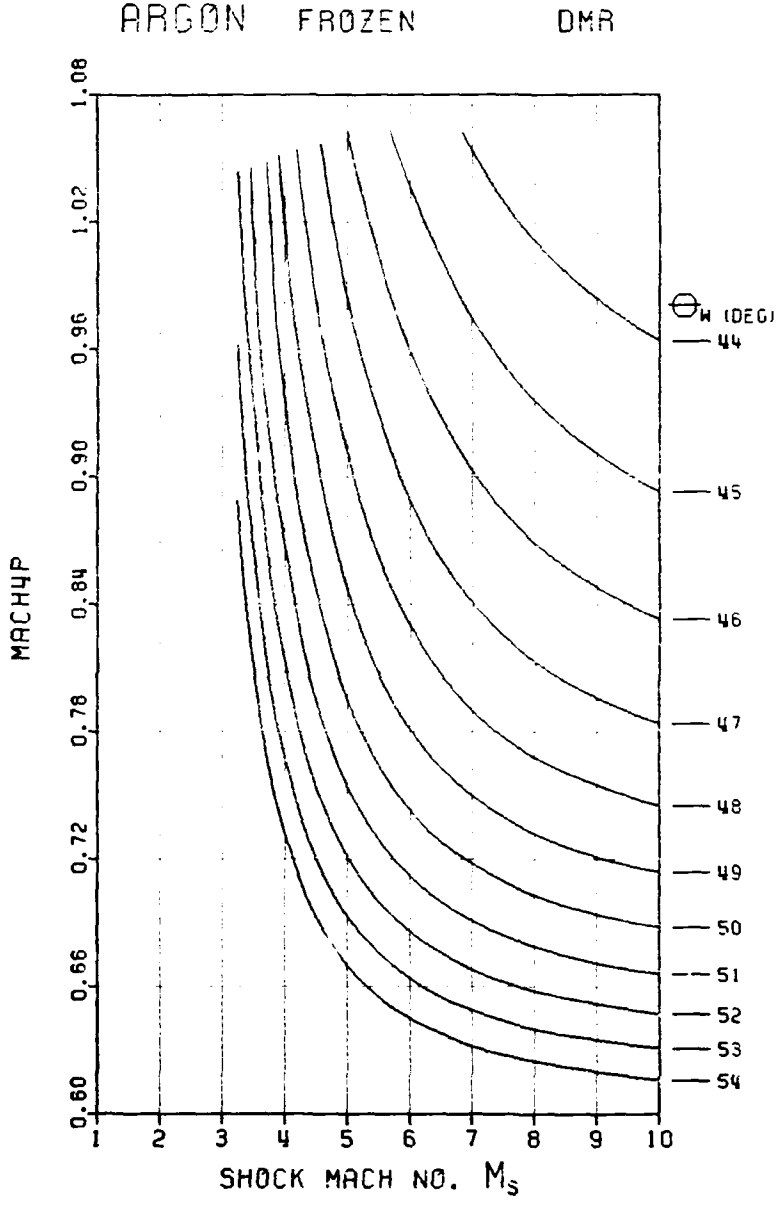

ARGON FROZEN DMR
RH04/RH00
10.20
9.60
9.00
8.40
7.80
7.20
6.60
6.00
5.40
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

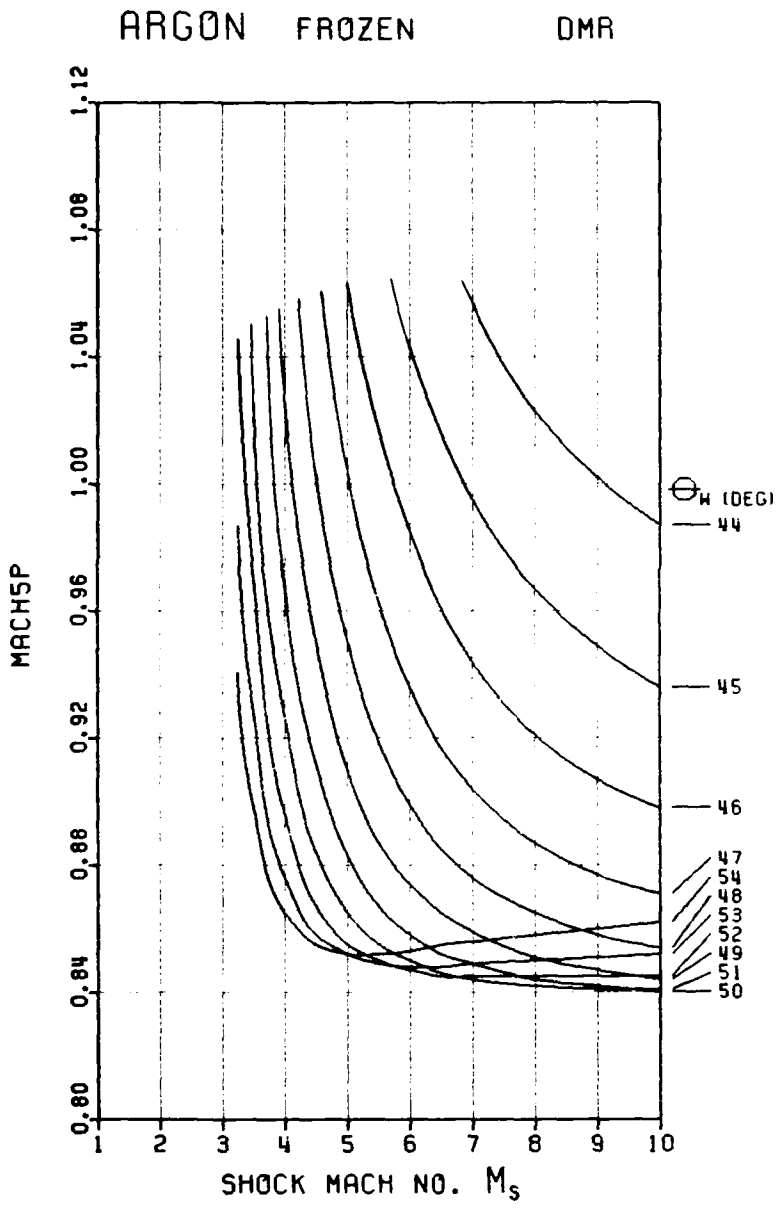

ARGON FROZEN DMR
RH05/RH00
11.00
10.30
9.60
8.90
8.20
7.50
6.80
6.10
5.40
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

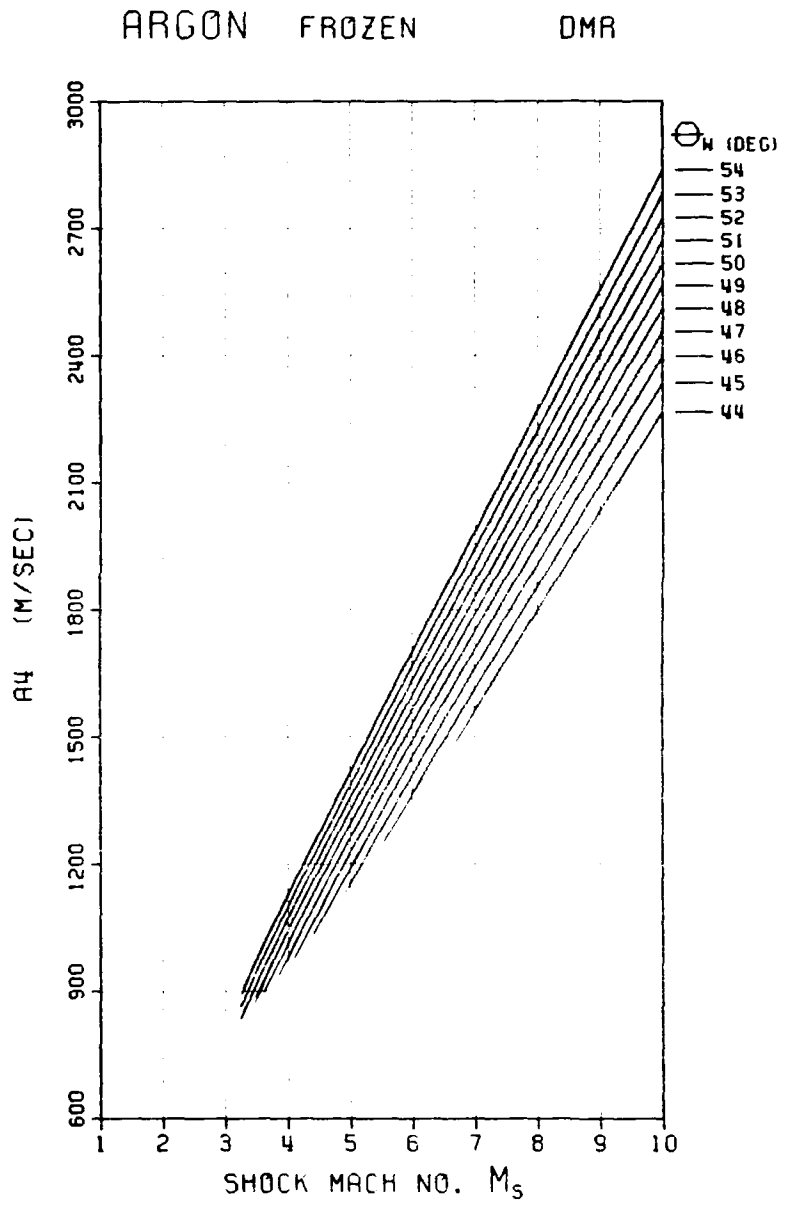

ARGON FROZEN DMR
P4/P0 AND P5/P0
SHOCK MACH NO. M_s
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

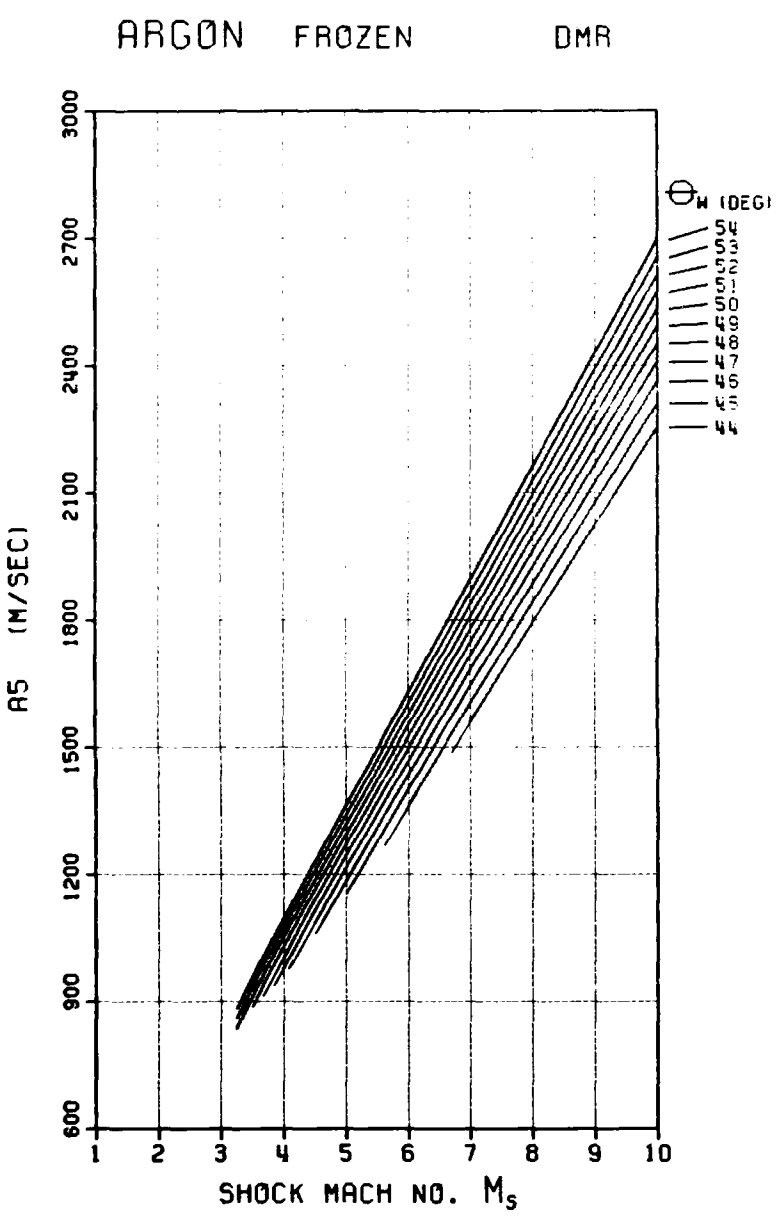

ARGON FROZEN DMR
MACH1P
SHOCK MACH NO. M_s
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

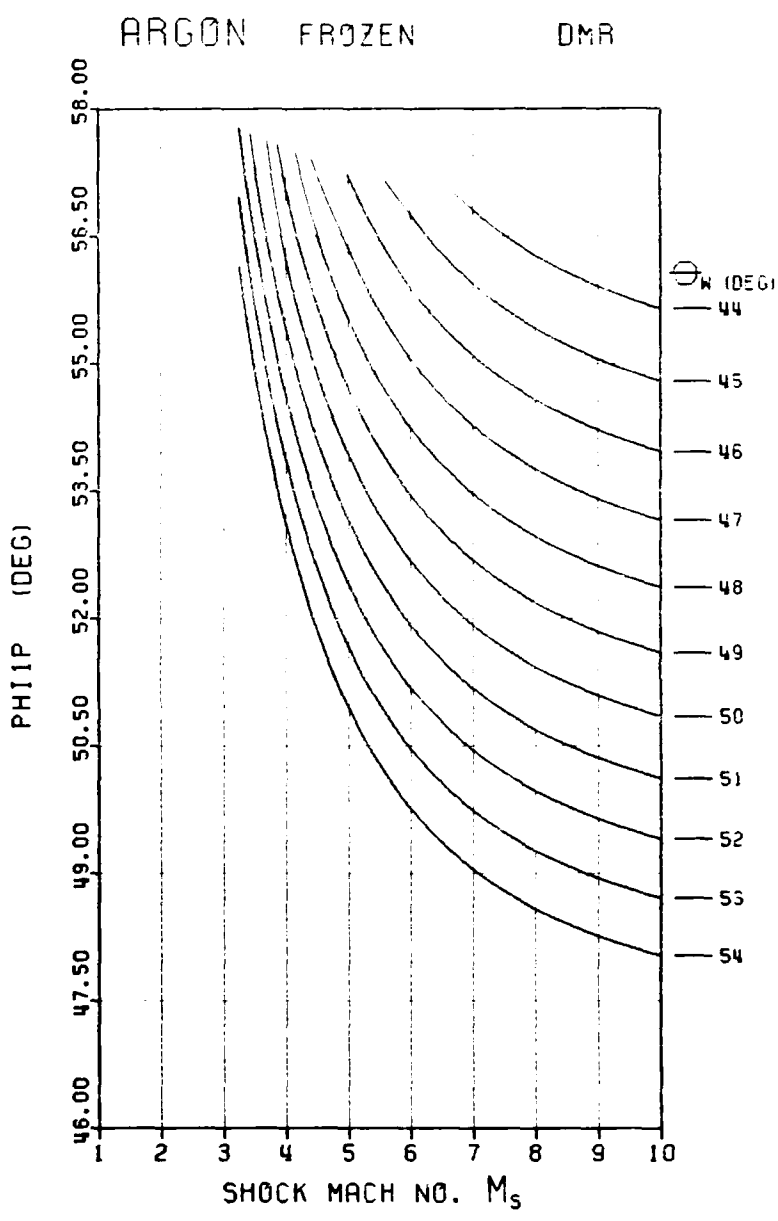

ARGON FROZEN DMR
MACH2P
1.04
1.08
1.12
1.16
1.20
1.24
1.28
1.32
1.36
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

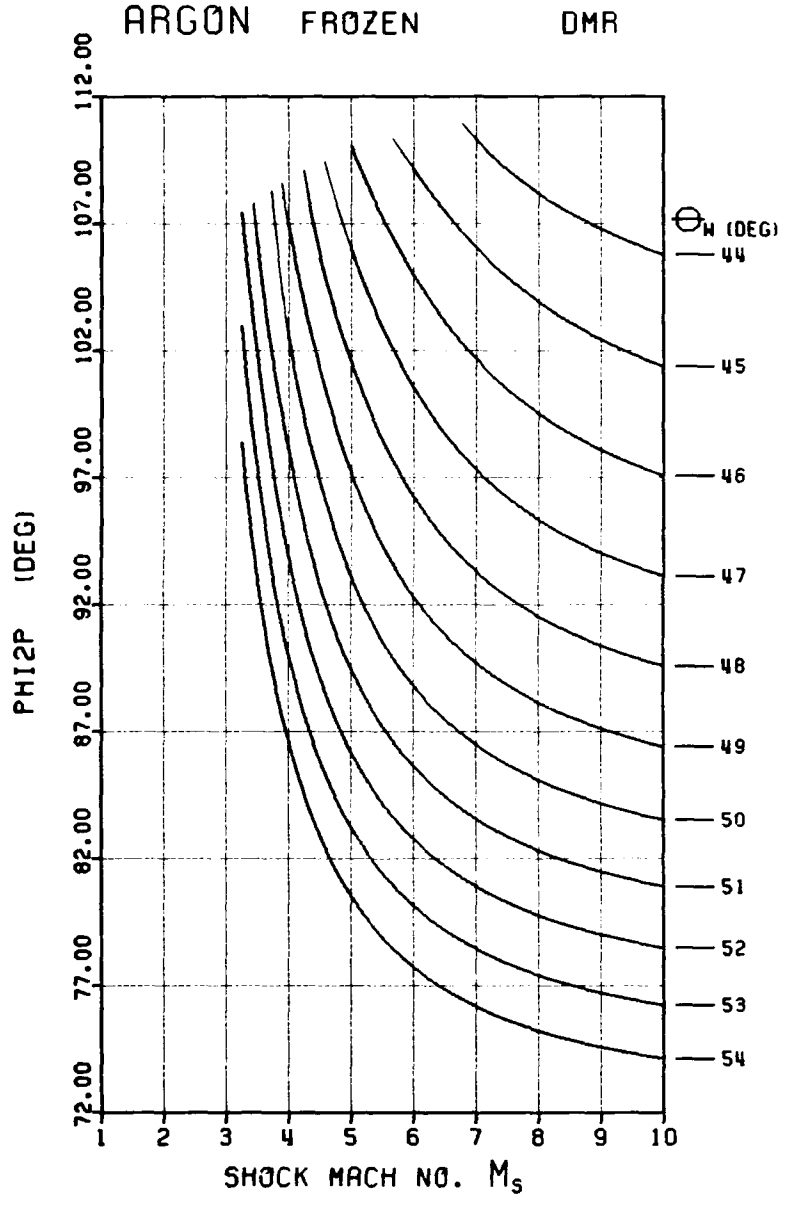

ARGON FROZEN DMR
MACH4P
0.60
0.66
0.72
0.78
0.84
0.90
0.96
1.02
1.08
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
44
45
46
47
48
49
50
51
52
53
54

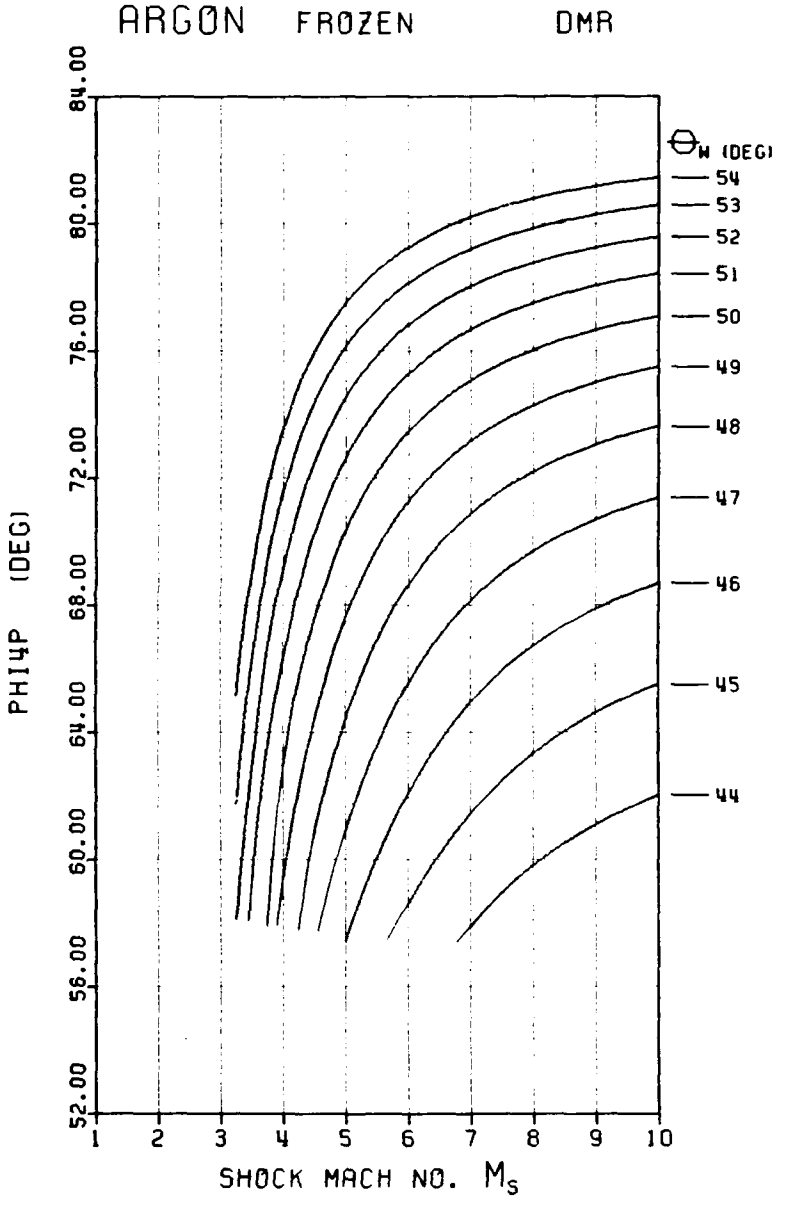

ARGON FROZEN DMR
MACHSP
SHOCK MACH NO. M_S
Θ_W (DEG)
44
45
46
47
54
48
53
52
49
51
50

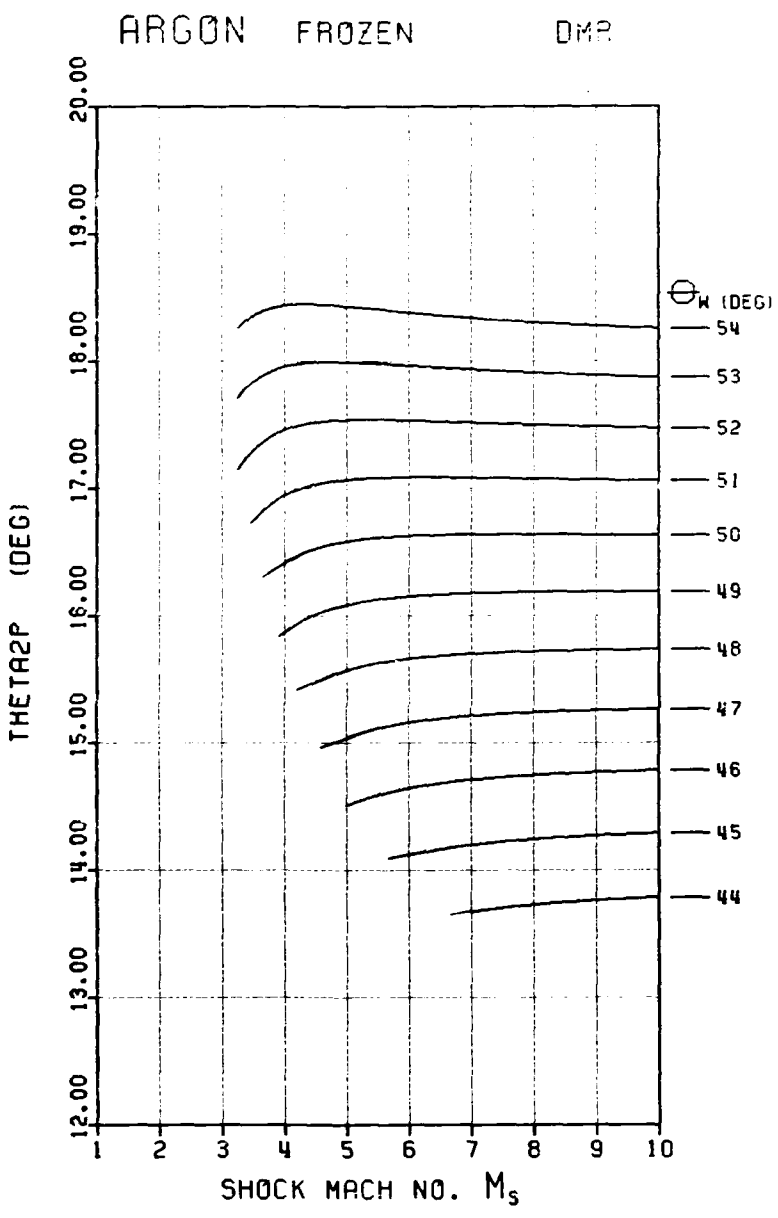

ARGON FROZEN DMR
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

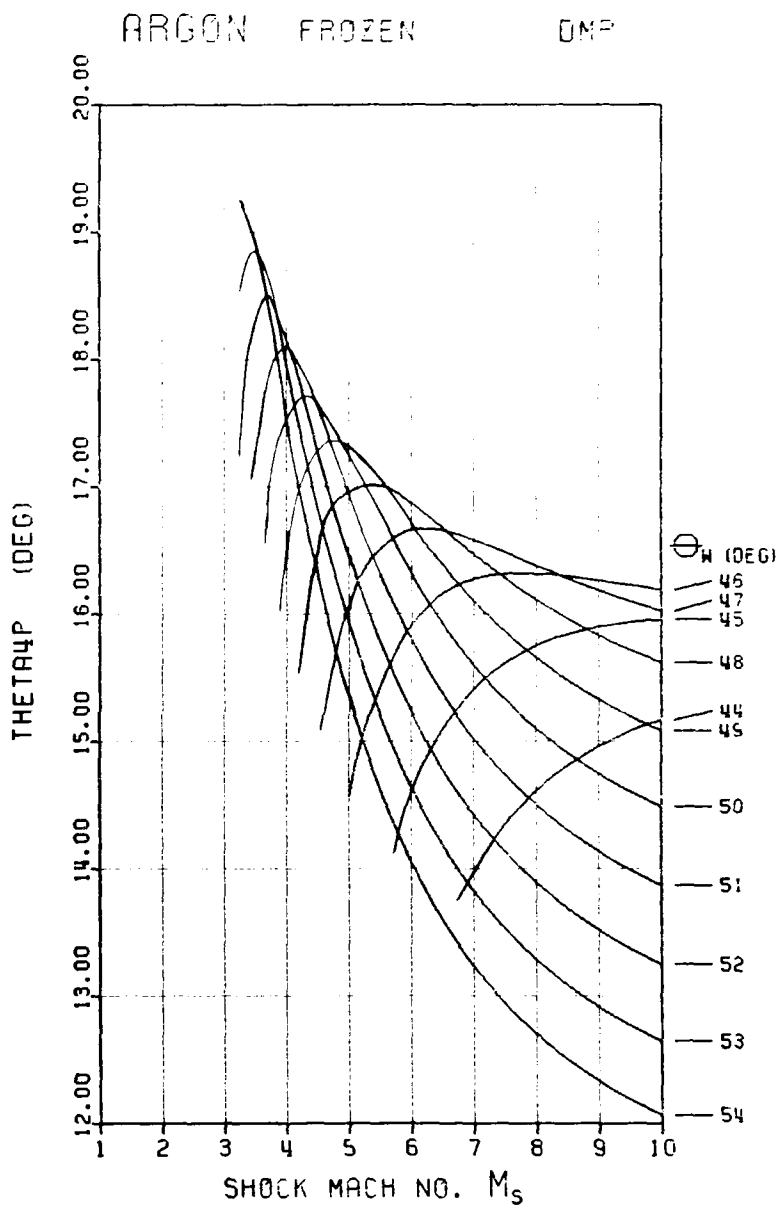

ARGON FROZEN DMR
A5 (M/SEC)
SHOCK MACH NO. M_S
θ_W (DEG)

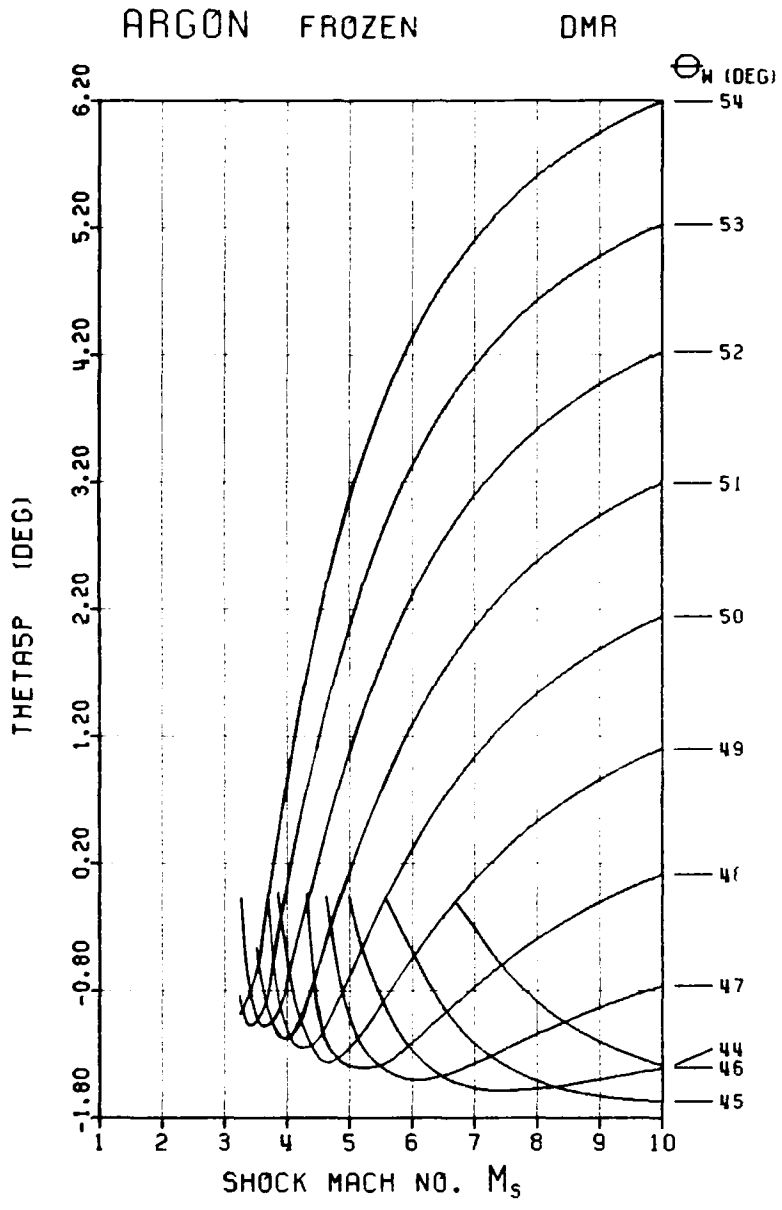

ARGON FROZEN DMR
PHI1P (DEG)
SHOCK MACH NO. M_S
θ_W (DEG)

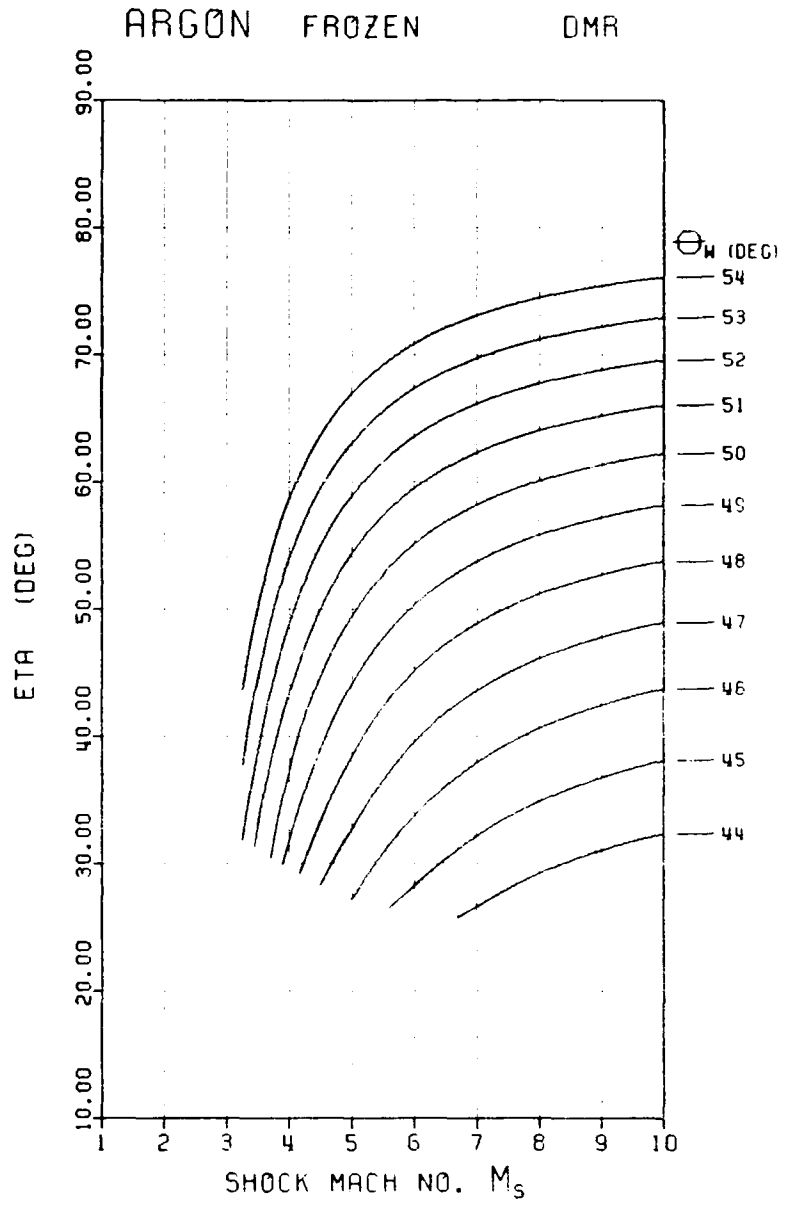

ARGON FROZEN DMR
PHI2P (DEG)
112.00
107.00
102.00
97.00
92.00
87.00
82.00
77.00
72.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
44
45
46
47
48
49
50
51
52
53
54

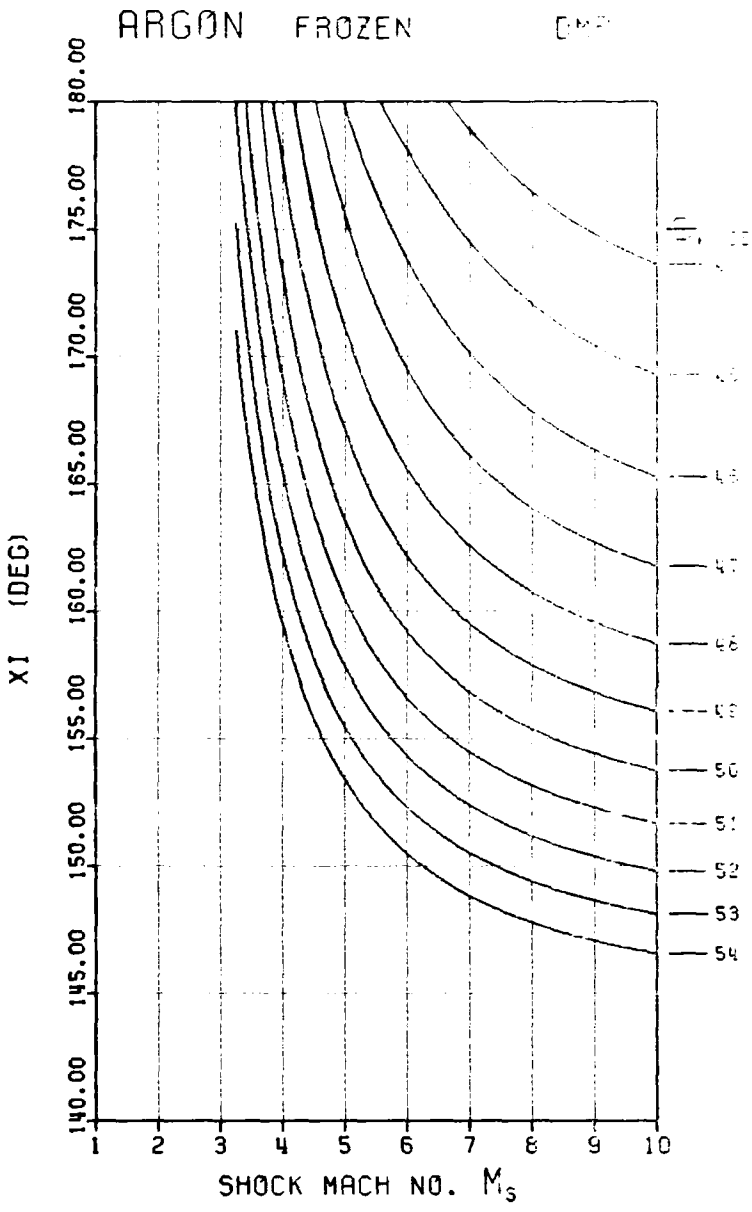

ARGON FROZEN DMR
PHI4P (DEG)
84.00
80.00
76.00
72.00
68.00
64.00
60.00
56.00
52.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44

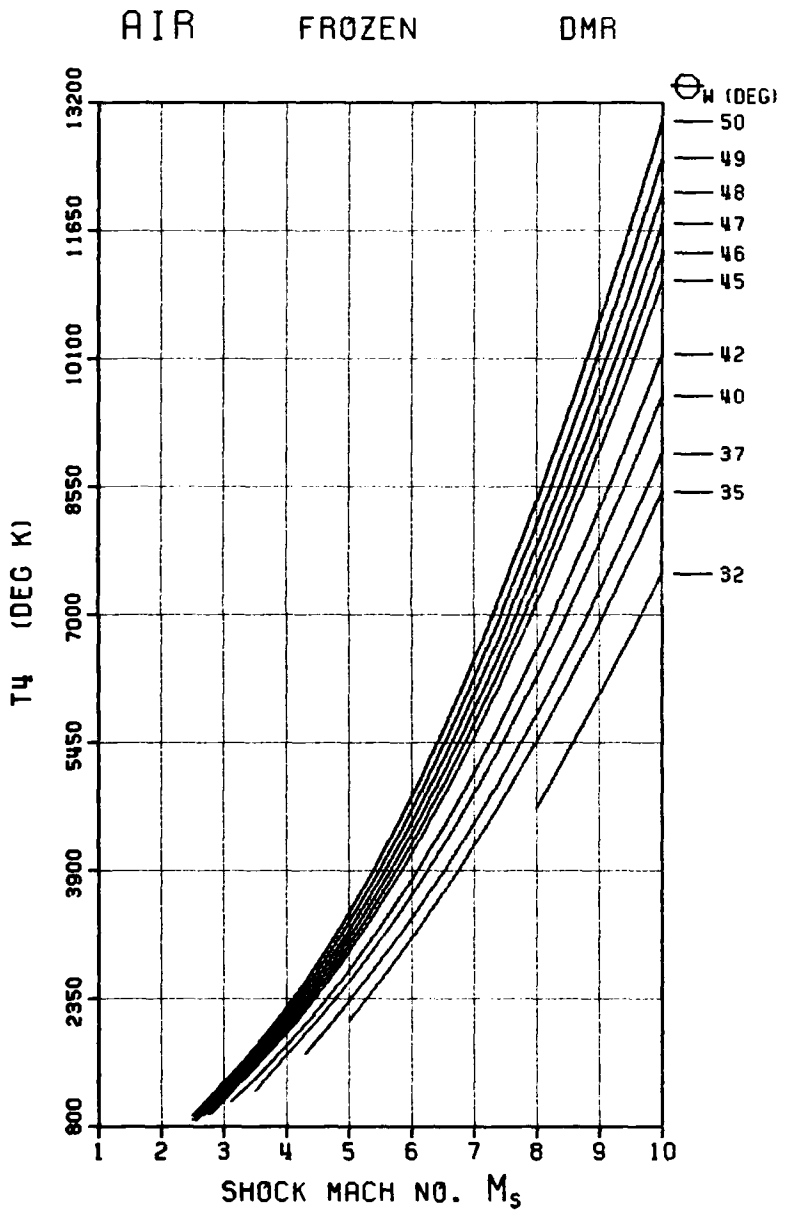

ARGON FROZEN DMP
THETA2P (DEG)
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
54
53
52
51
50
49
48
47
46
45
44

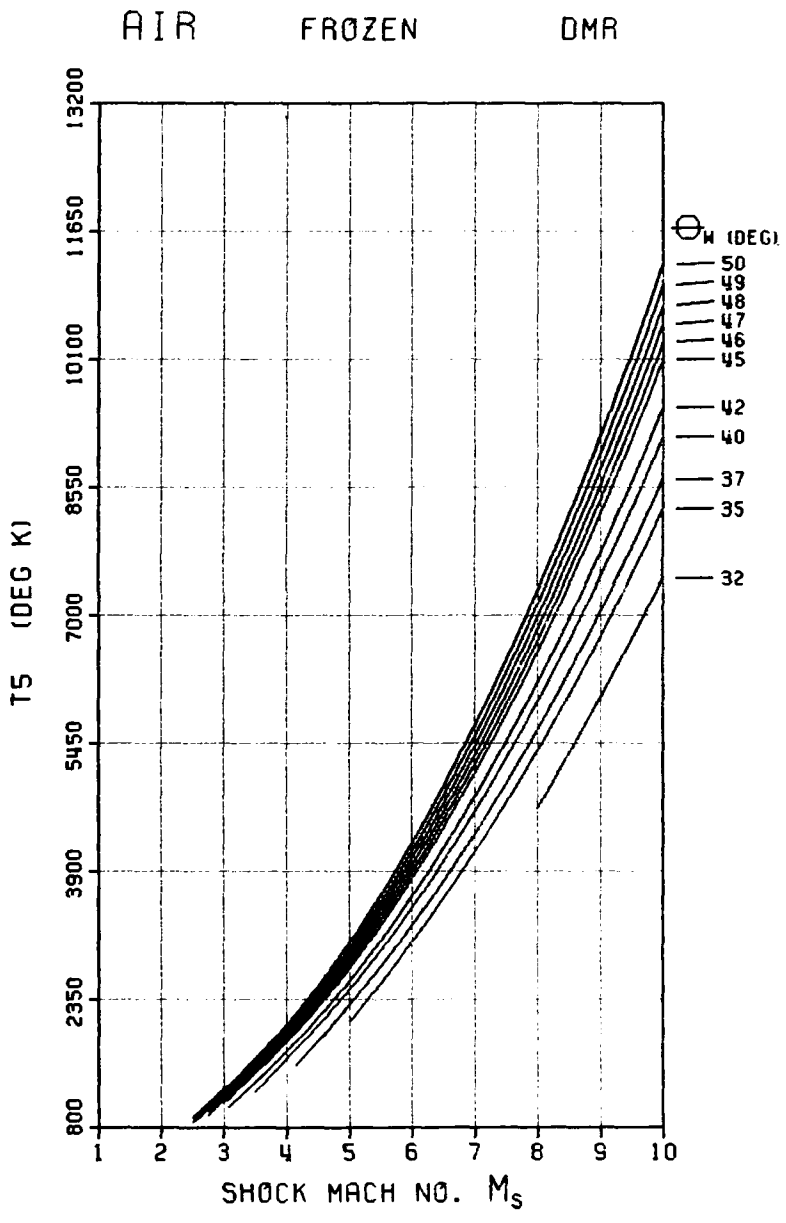

ARGON FROZEN DMP
THETA4P (DEG)
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
46
47
45
48
44
49
50
51
52
53
54

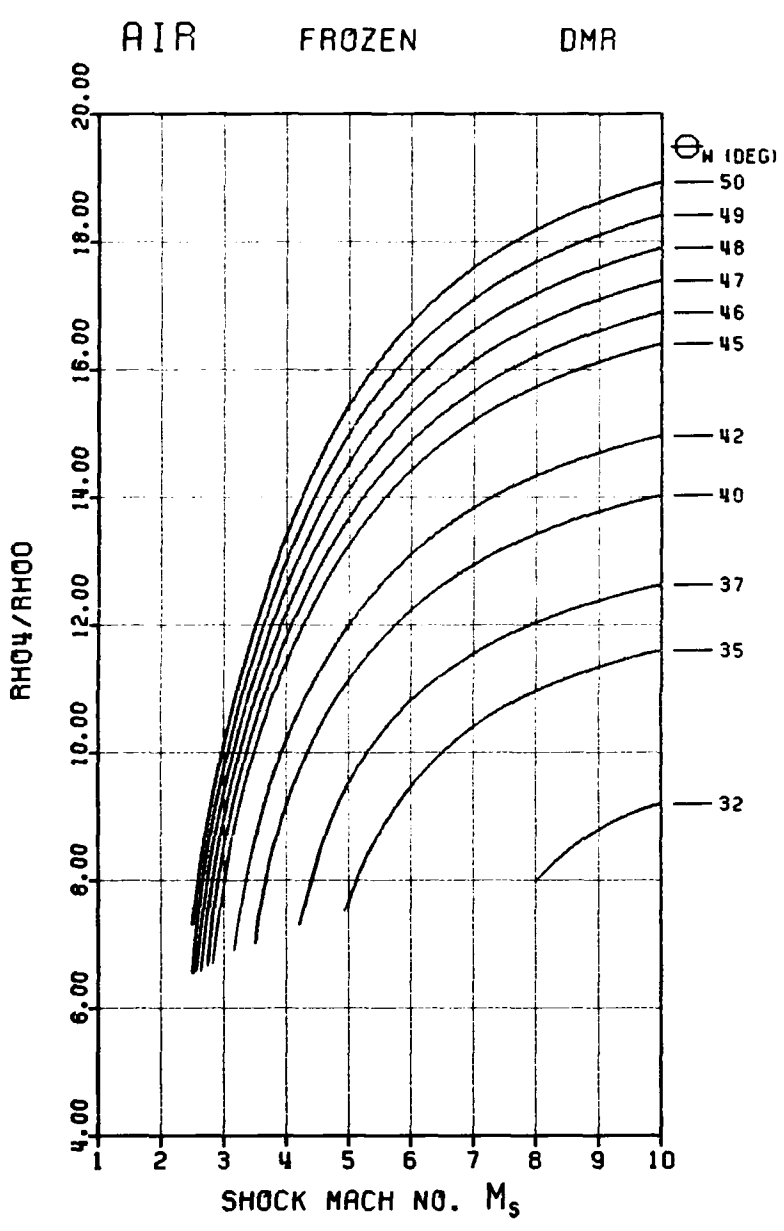

ARGON FROZEN DMR
Θ_W (DEG)
54
53
52
51
50
49
47
44
46
45
THETA5P (DEG)
6.20
5.20
4.20
3.20
2.20
1.20
0.20
-0.80
-1.80
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

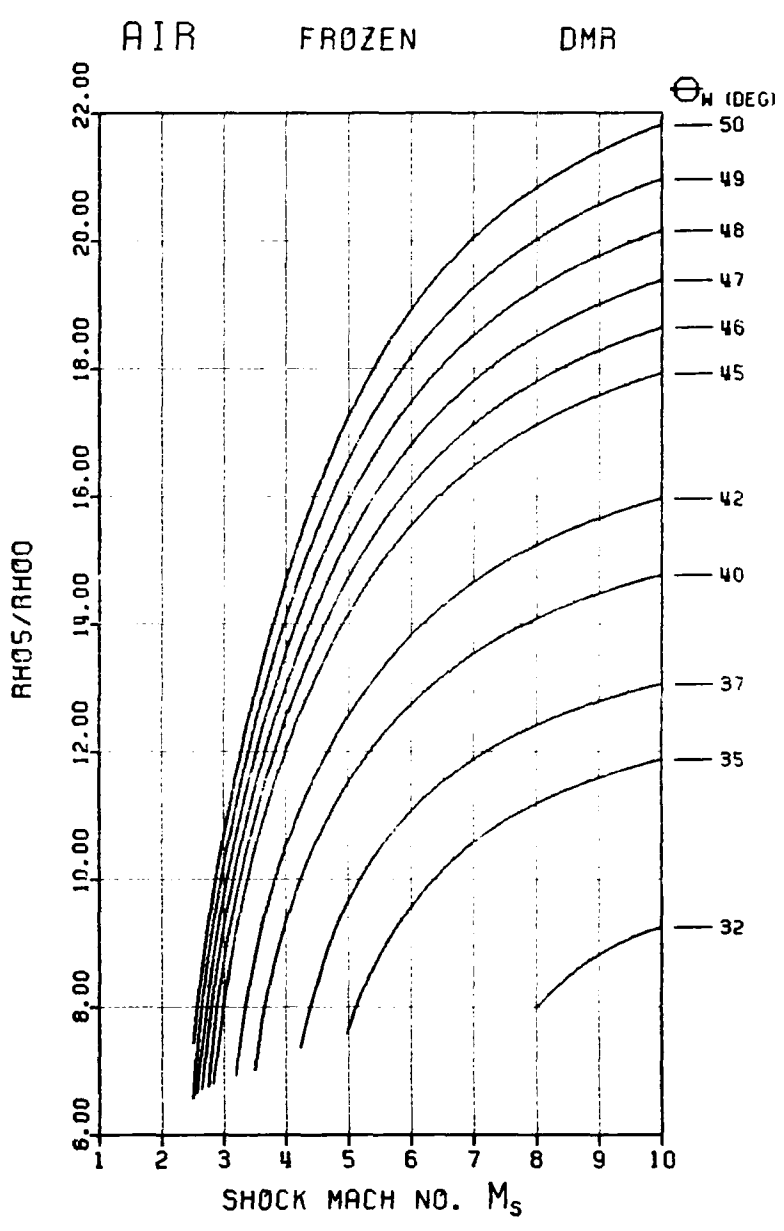

ARGON FROZEN DMR
Θ_W (DEG)
54
53
52
51
50
49
48
47
46
45
44
ETA (DEG)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

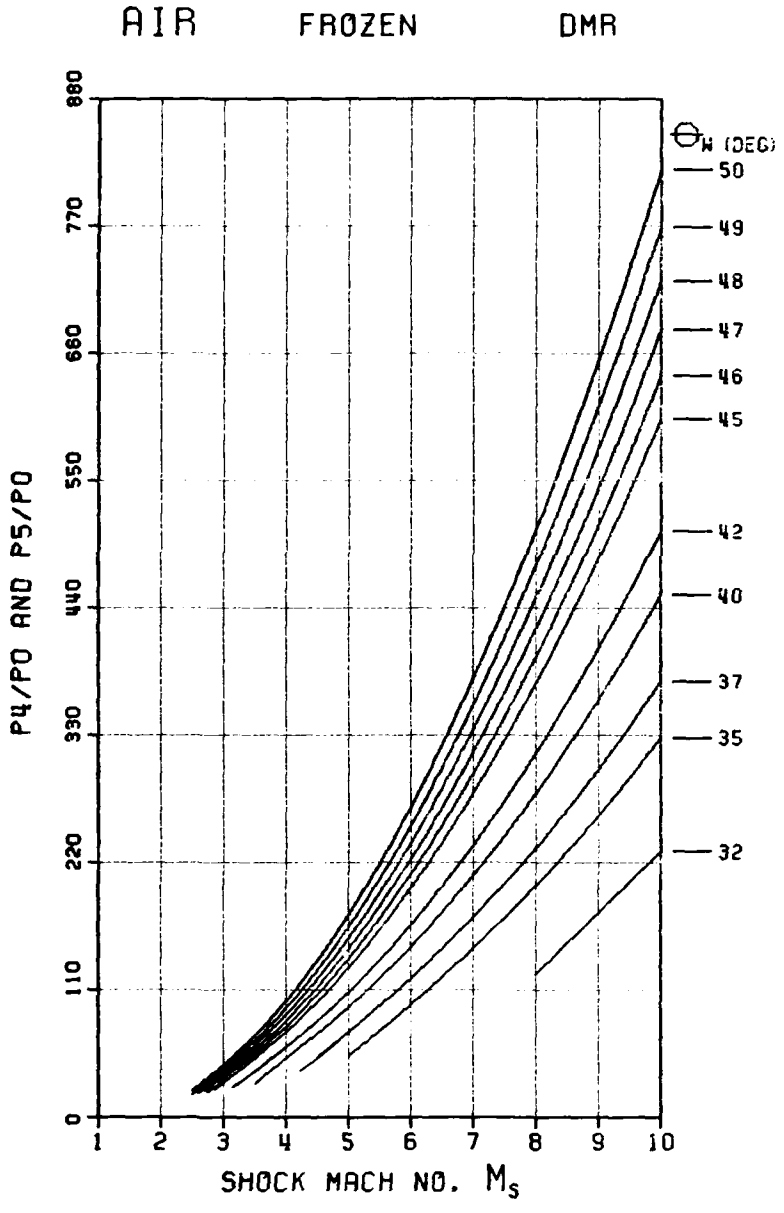

ARGON FROZEN
XI (DEG)
180.00
175.00
170.00
165.00
160.00
155.00
150.00
145.00
140.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
50
51
52
53
54

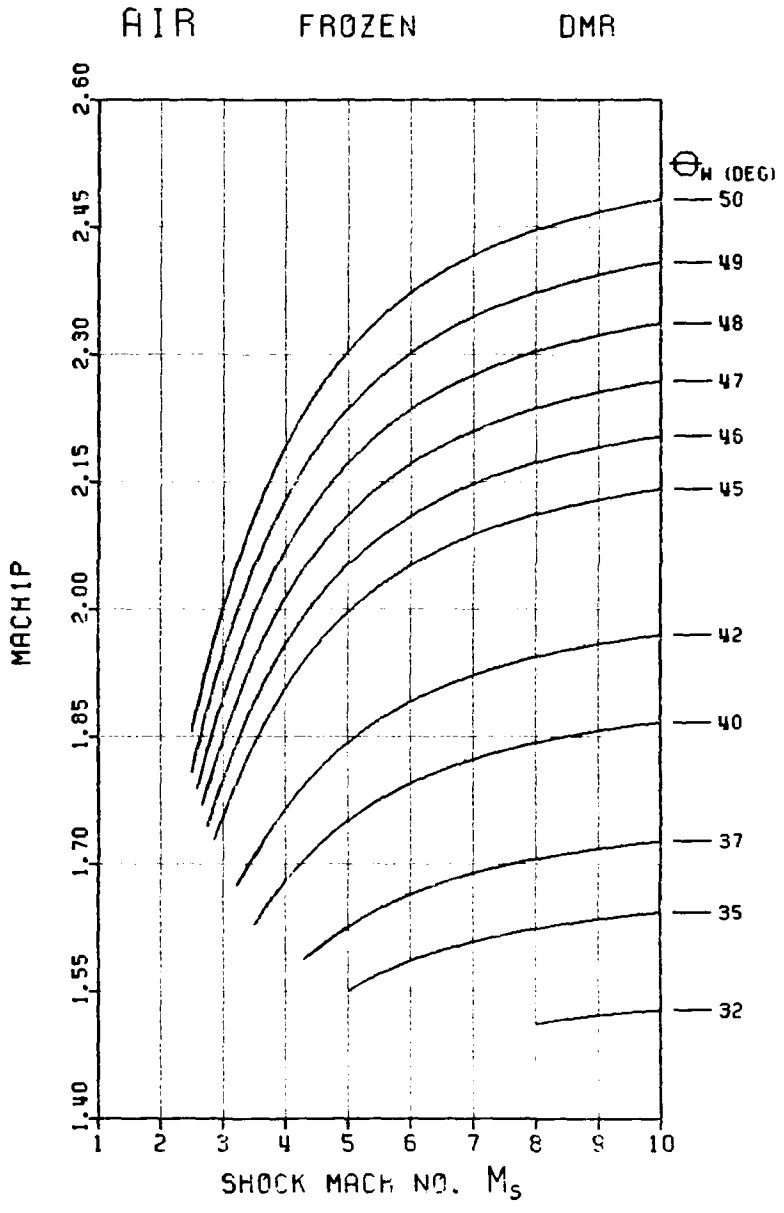

AIR FROZEN DMR
T4 (DEG K)
13200
11650
10100
8550
7000
5450
3900
2350
800
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

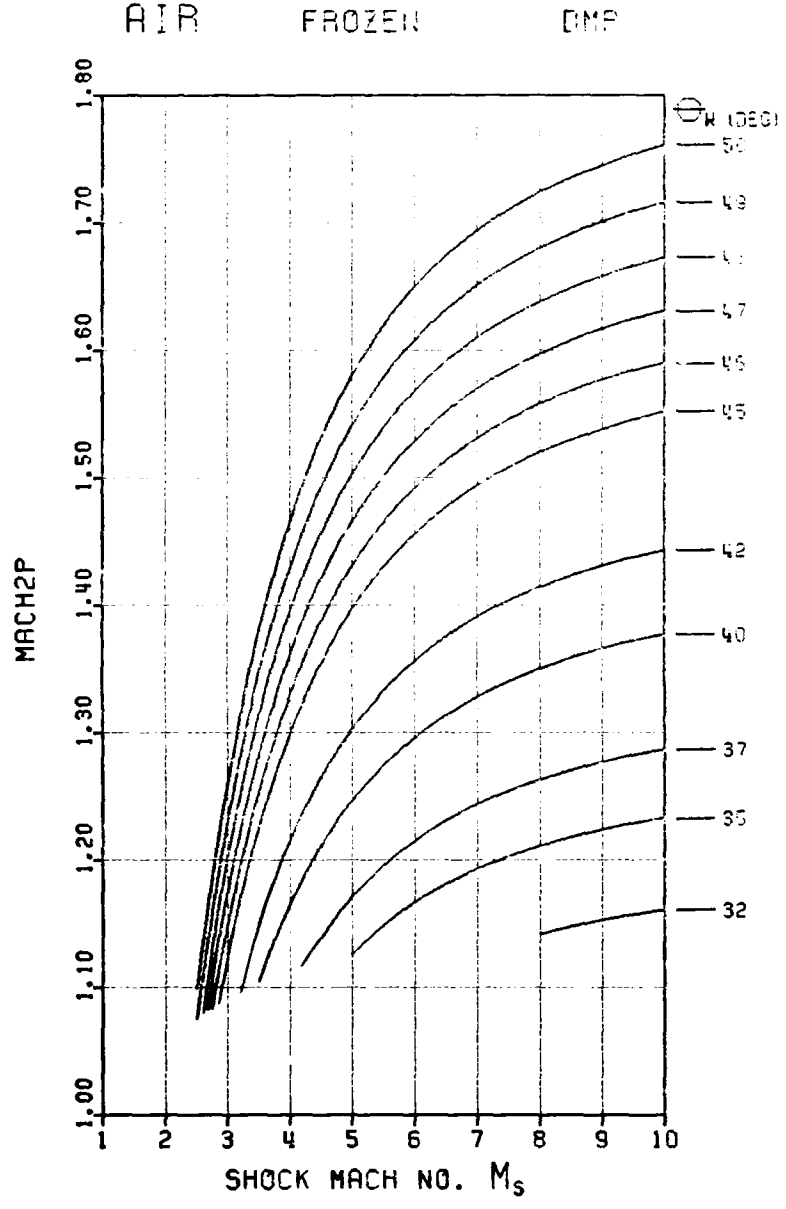

AIR FROZEN DMR
T5 (DEG K)
13200
11650
10100
8550
7000
5450
3900
2350
800
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

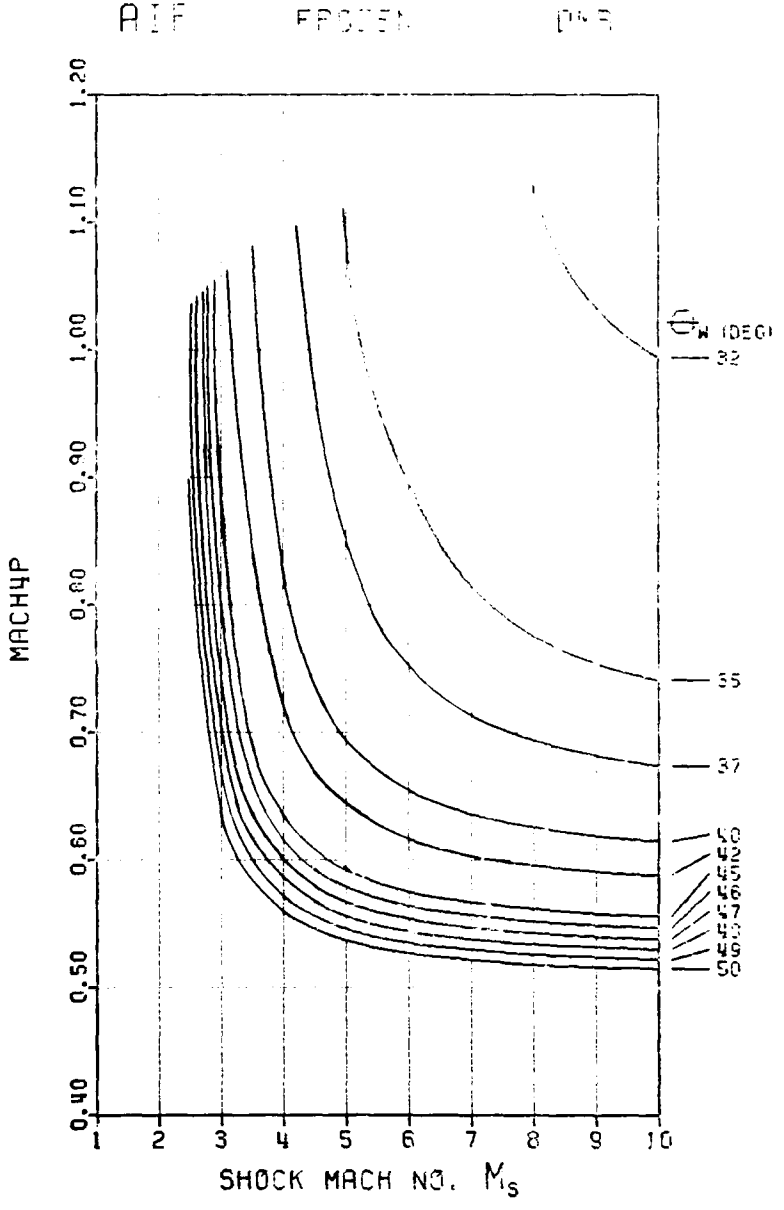

AIR FROZEN DMR
RH04/RH00
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

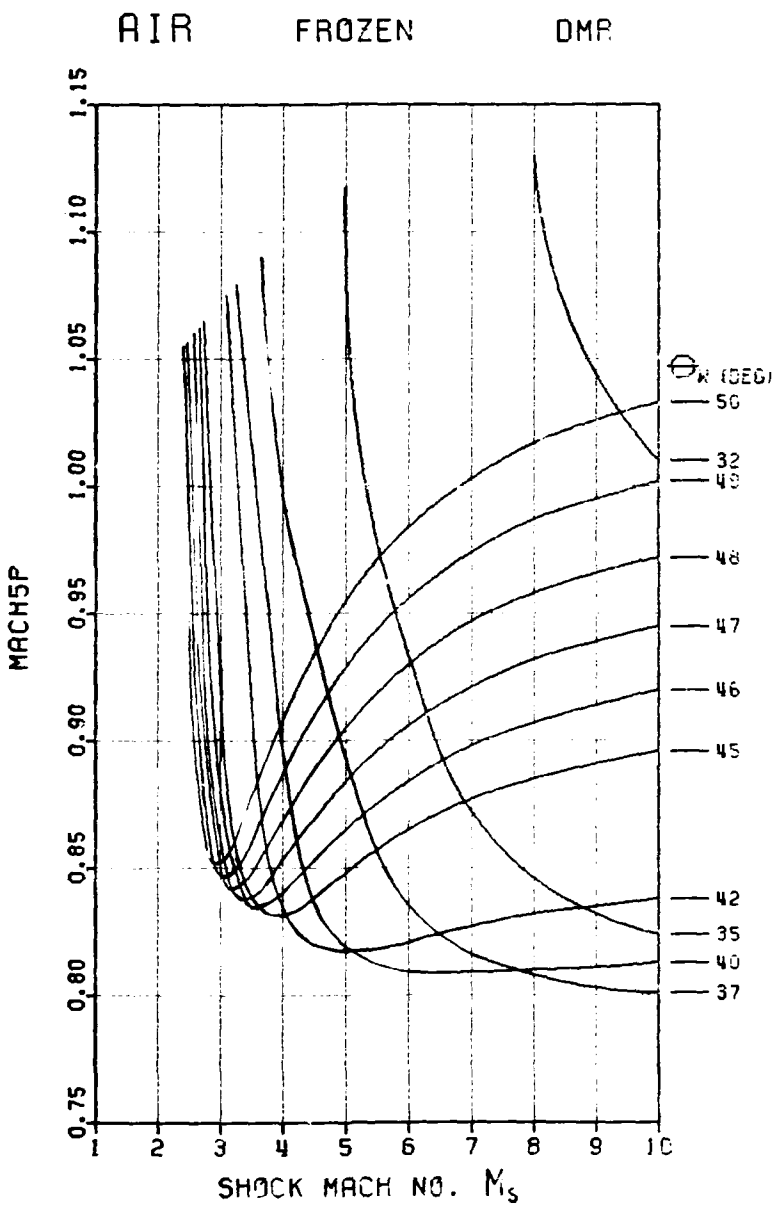

AIR FROZEN DMR
RH05/RH00
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

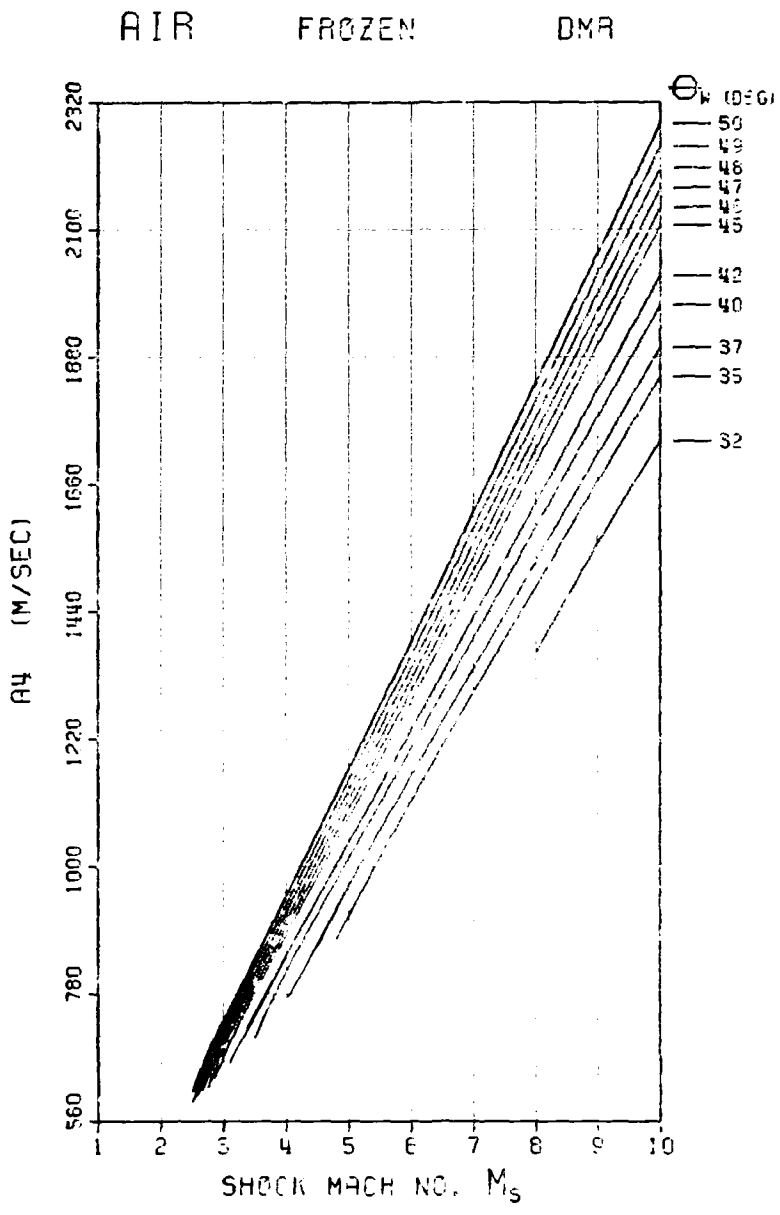

AIR FROZEN DMR
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
0
110
220
330
440
550
660
770
880
1
2
3
4
5
6
7
8
9
10

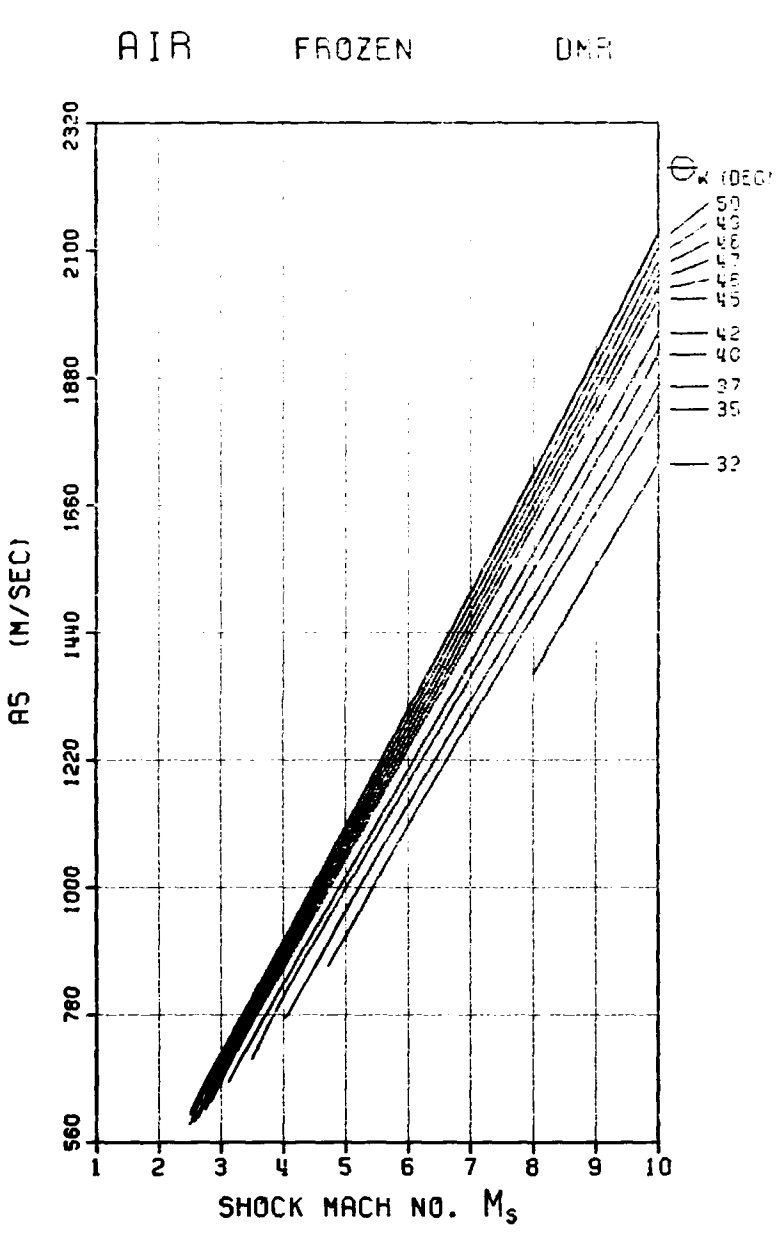

AIR FROZEN DMR
MACH1P
SHOCK MACH NO. M_S
θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
1.40
1.55
1.70
1.85
2.00
2.15
2.30
2.45
2.60
1
2
3
4
5
6
7
8
9
10

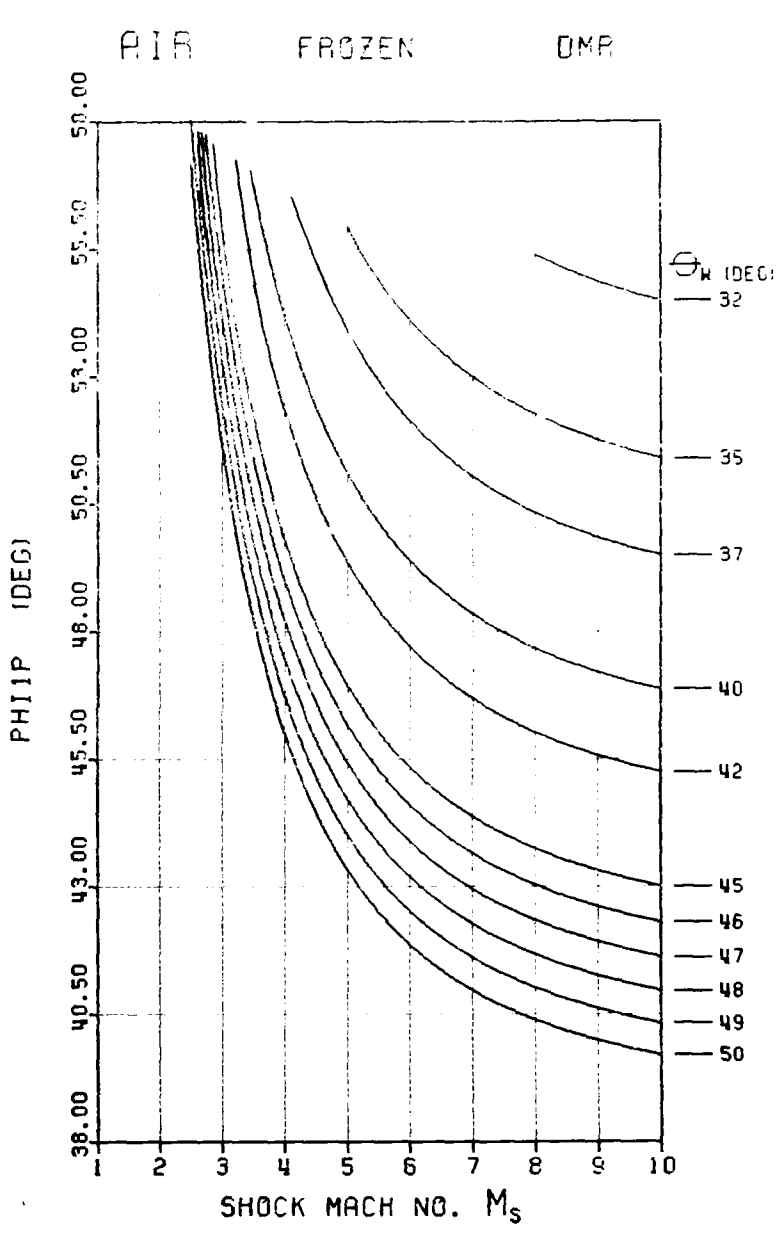

AIR FROZEN DMP
MACH2P
SHOCK MACH NO. M_s
Θ_w (DEG)
50
42
40
37
35
32

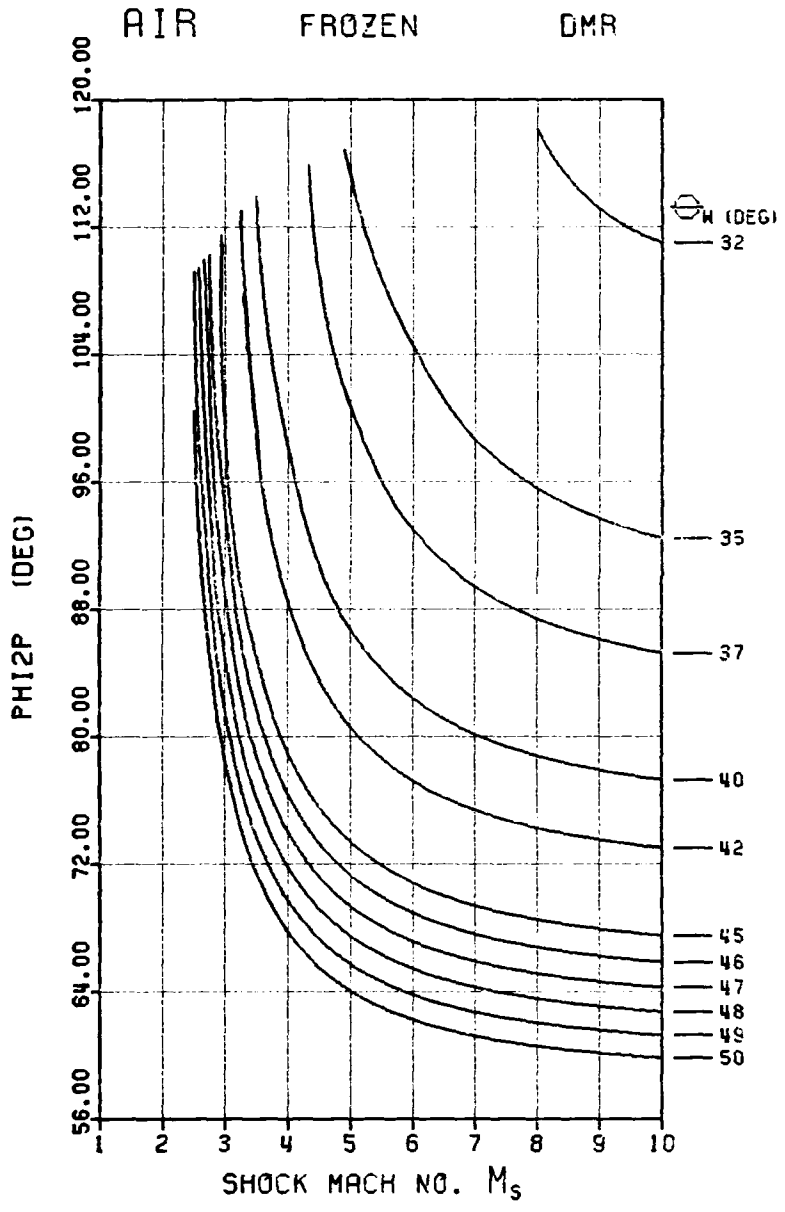

AIR FROZEN DMP
MACH4P
SHOCK MACH NO. M_s
Θ_w (DEG)
32
35
37
50


AIR FROZEN DMR
MACH5P
SHOCK MACH NO. M_S
Θ_W (DEG)
50
32
48
47
46
45
42
35
40
37


AIR FROZEN DMR
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
50
46
45
42
40
37
35
32


AIR FROZEN DMR
A5 (M/SEC)
560
780
1000
1220
1440
1660
1880
2100
2320
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
45
42
40
37
35
32


AIR FROZEN DMR
PHI1P (DEG)
38.00
40.50
43.00
45.50
48.00
50.50
53.00
55.50
58.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
37
40
42
45
46
47
48
49
50


AIR FROZEN DMR
PHI2P (DEG)
120.00
112.00
104.00
96.00
88.00
80.00
72.00
64.00
56.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
32
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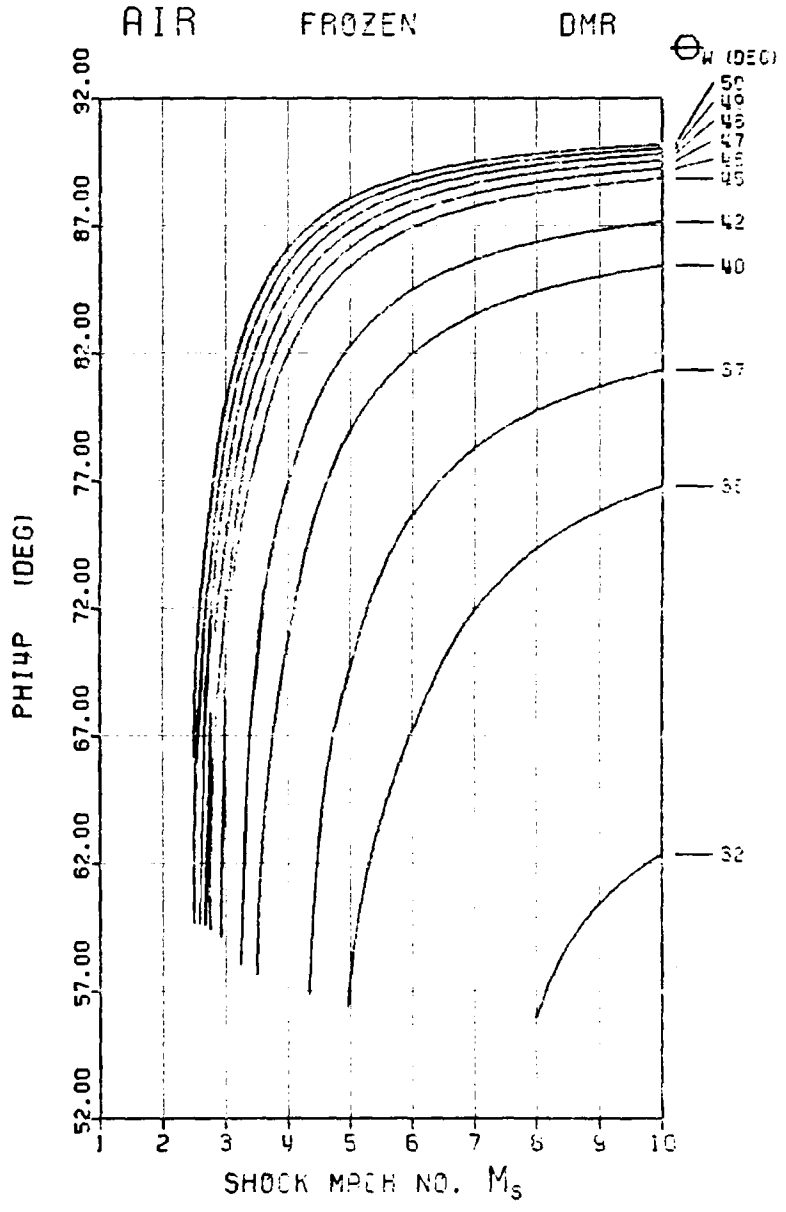
AIR FROZEN DMR
PHI4P (DEG)
92.00
87.00
82.00
77.00
72.00
67.00
62.00
57.00
52.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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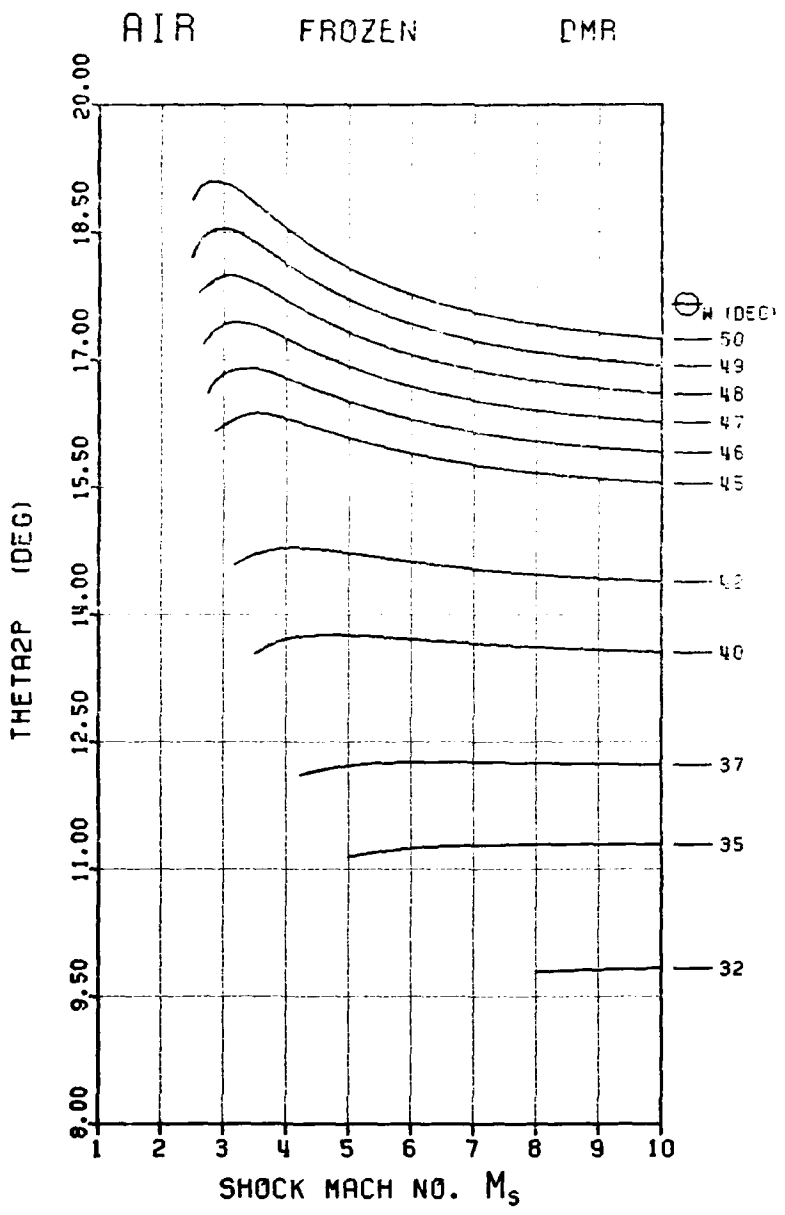
AIR FROZEN DMR
THETA2P (DEG)
SHOCK MACH NO. M_s
Θ_w (DEG)
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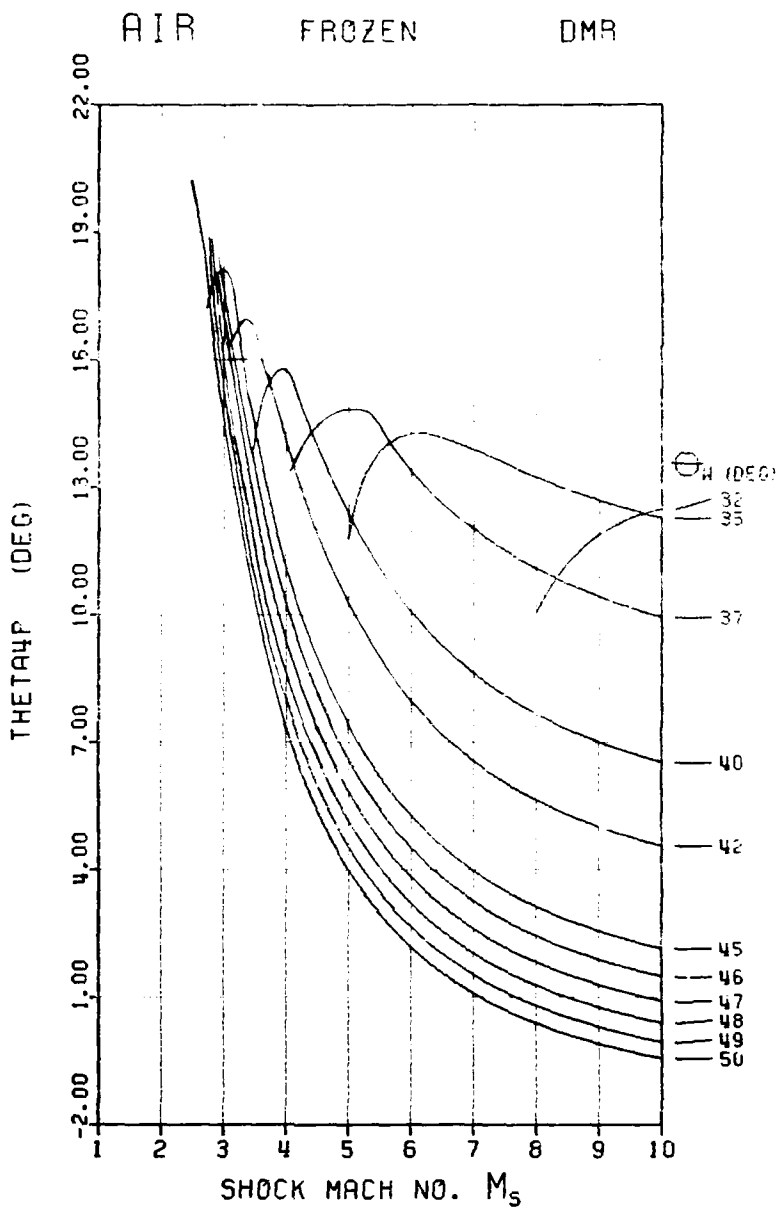
AIR FROZEN DMR
THETA4P (DEG)
SHOCK MACH NO. M_s
Θ_w (DEG)
32
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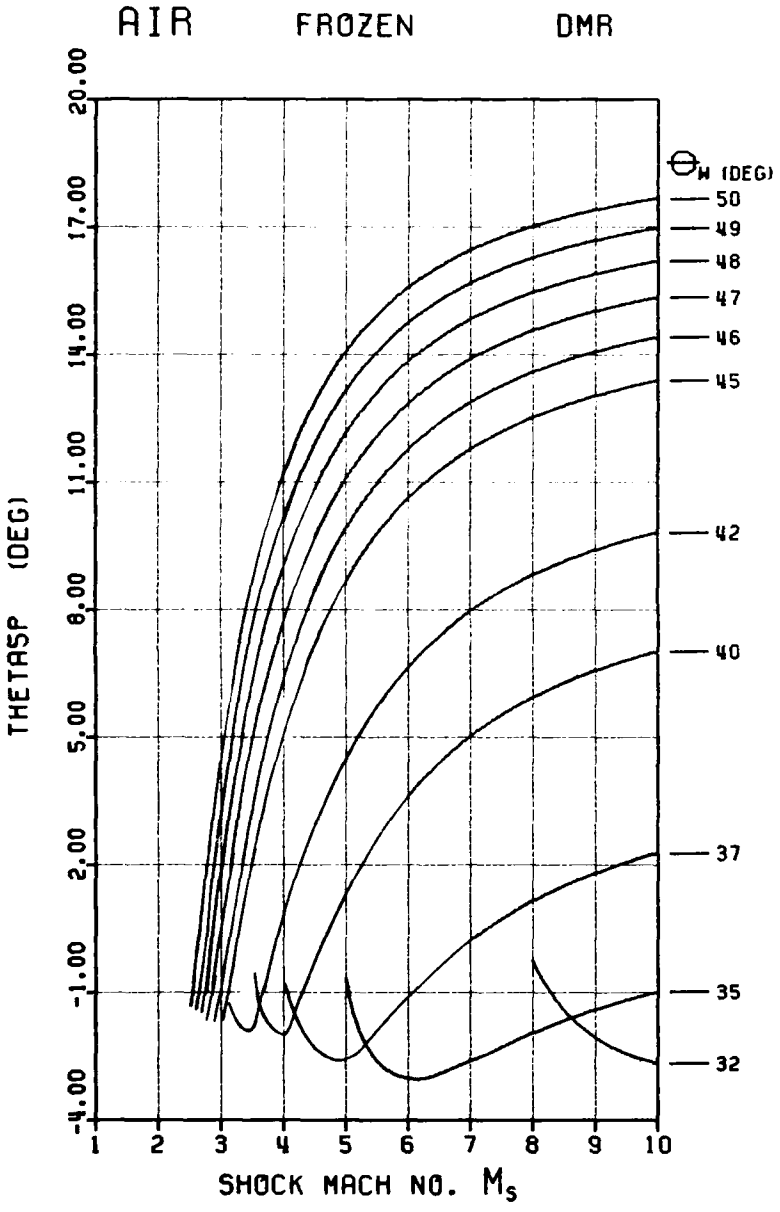
AIR FROZEN DMR
THETASP (DEG)
20.00
17.00
14.00
11.00
8.00
5.00
2.00
-1.00
-4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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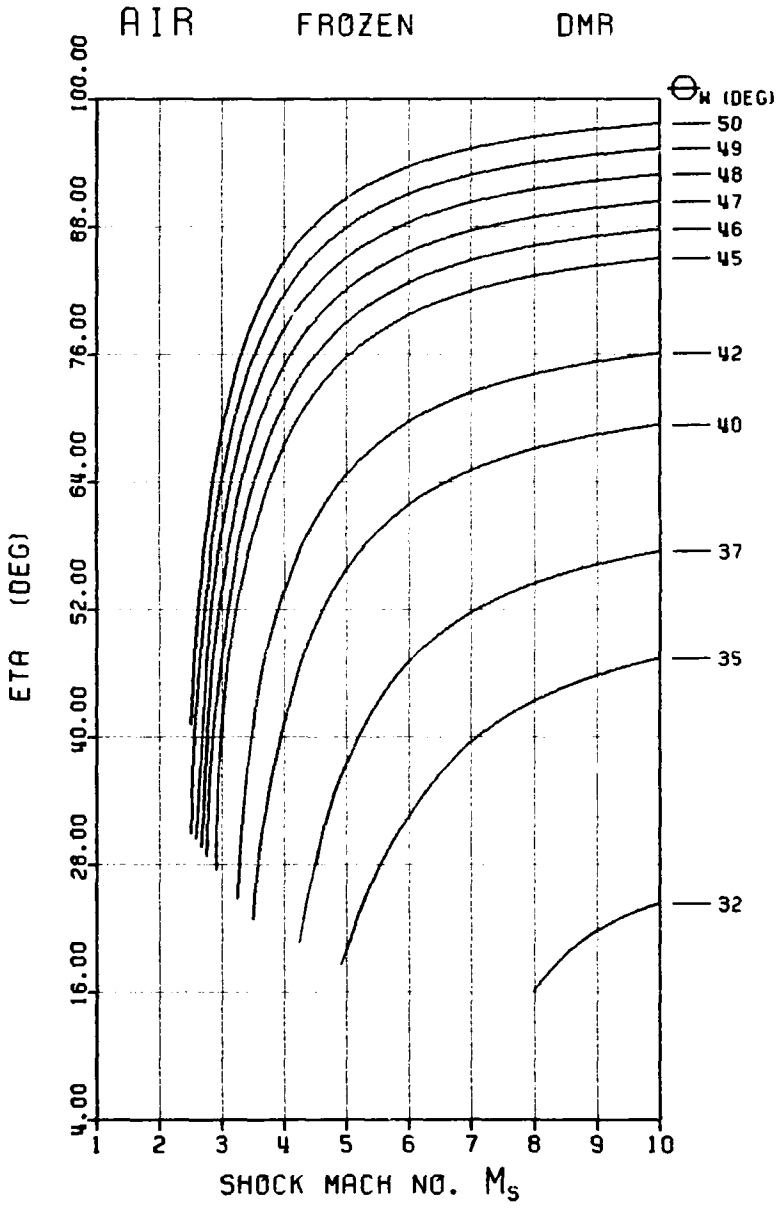
AIR FROZEN DMR
ETA (DEG)
100.00
88.00
76.00
64.00
52.00
40.00
28.00
16.00
4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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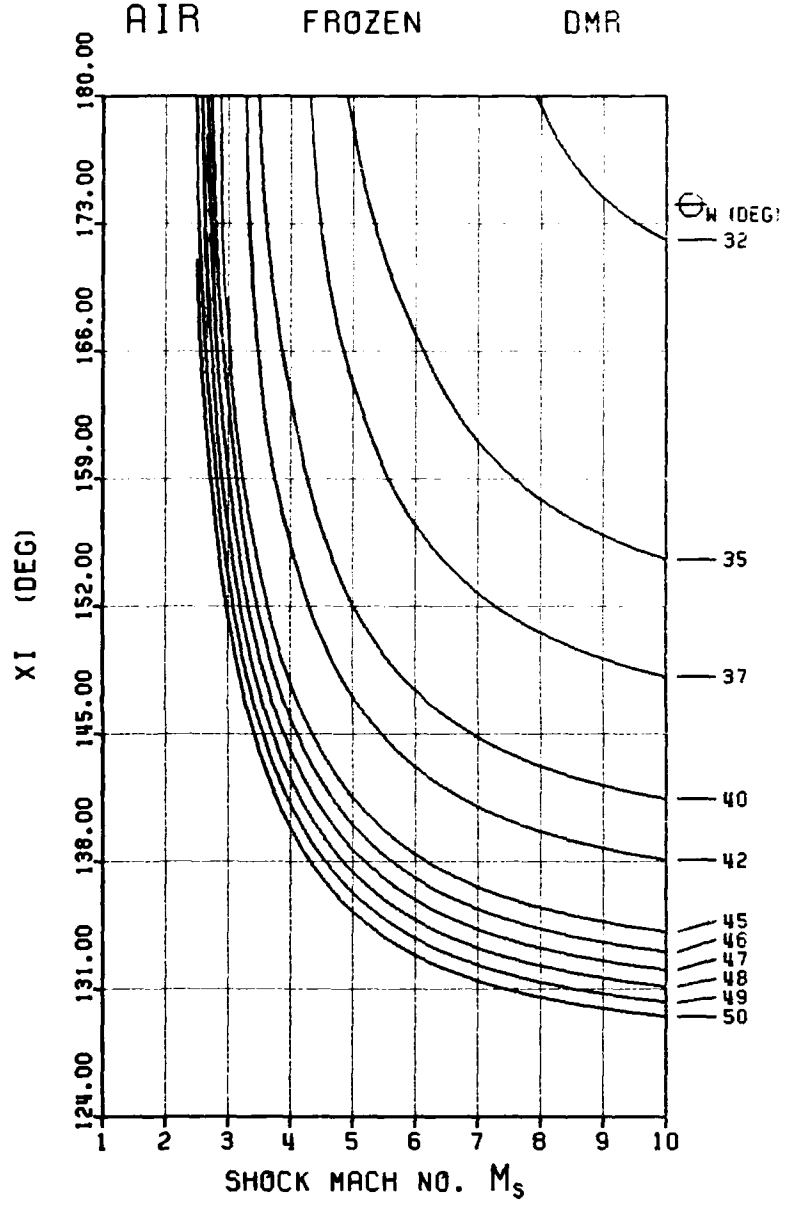
AIR FROZEN DMR
XI (DEG)
180.00
173.00
166.00
159.00
152.00
145.00
138.00
131.00
124.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
θ_W (DEG)
32
35
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42
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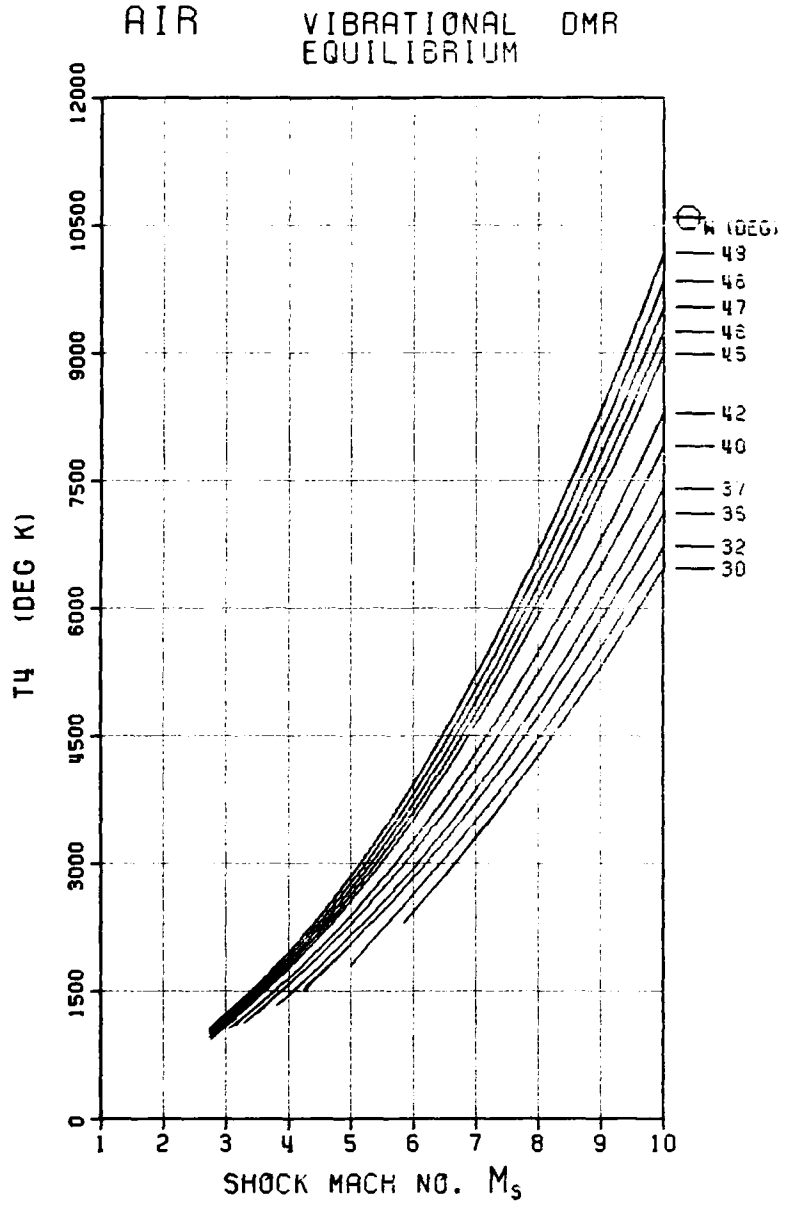
47
48
49
50


AIR
VIBRATIONAL EQUILIBRIUM
DMR
T4 (DEG K)
0
1500
3000
4500
6000
7500
9000
10500
12000
1
2
3
4
5
6
7
8
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10
SHOCK MACH NO. M_s
Θ_w (DEG)
49
48
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46
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37
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32
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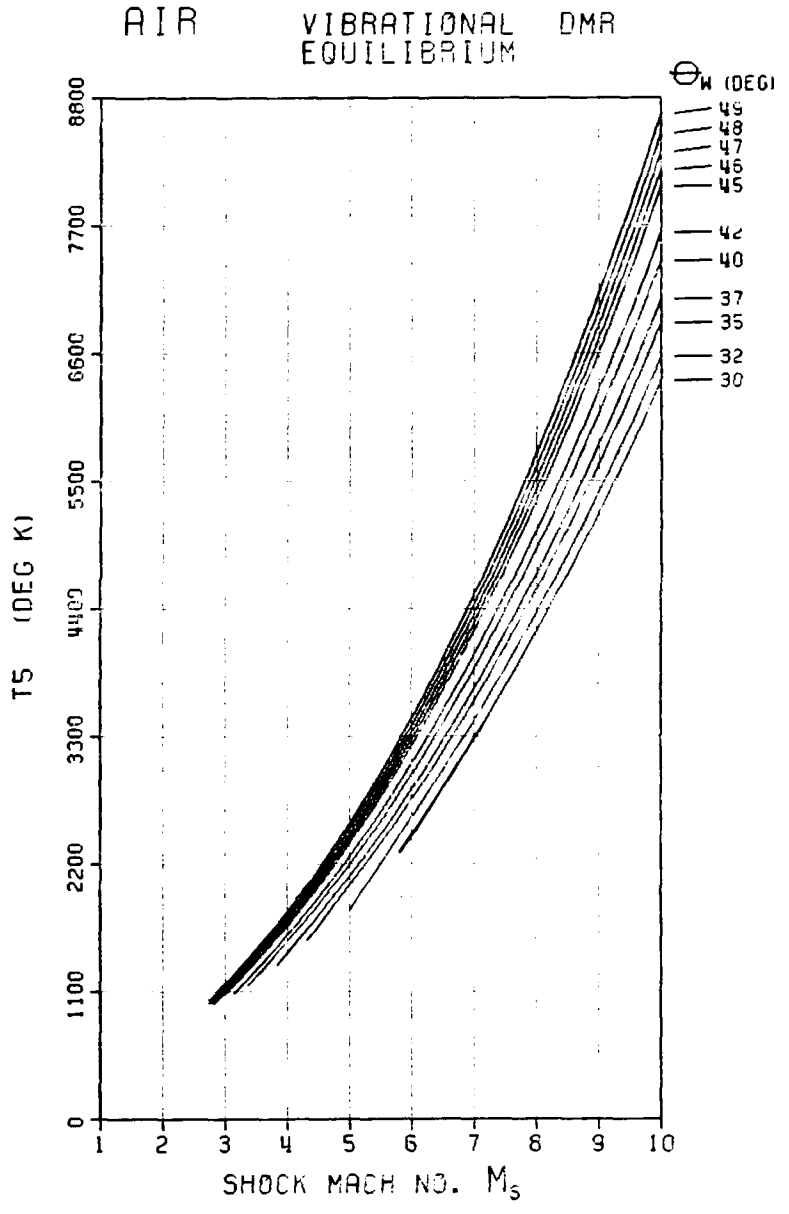
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VIBRATIONAL EQUILIBRIUM
DMR
T5 (DEG K)
0
1100
2200
3300
4400
5500
6600
7700
8800
1
2
3
4
5
6
7
8
9
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SHOCK MACH NO. M_s
Θ_w (DEG)
49
48
47
46
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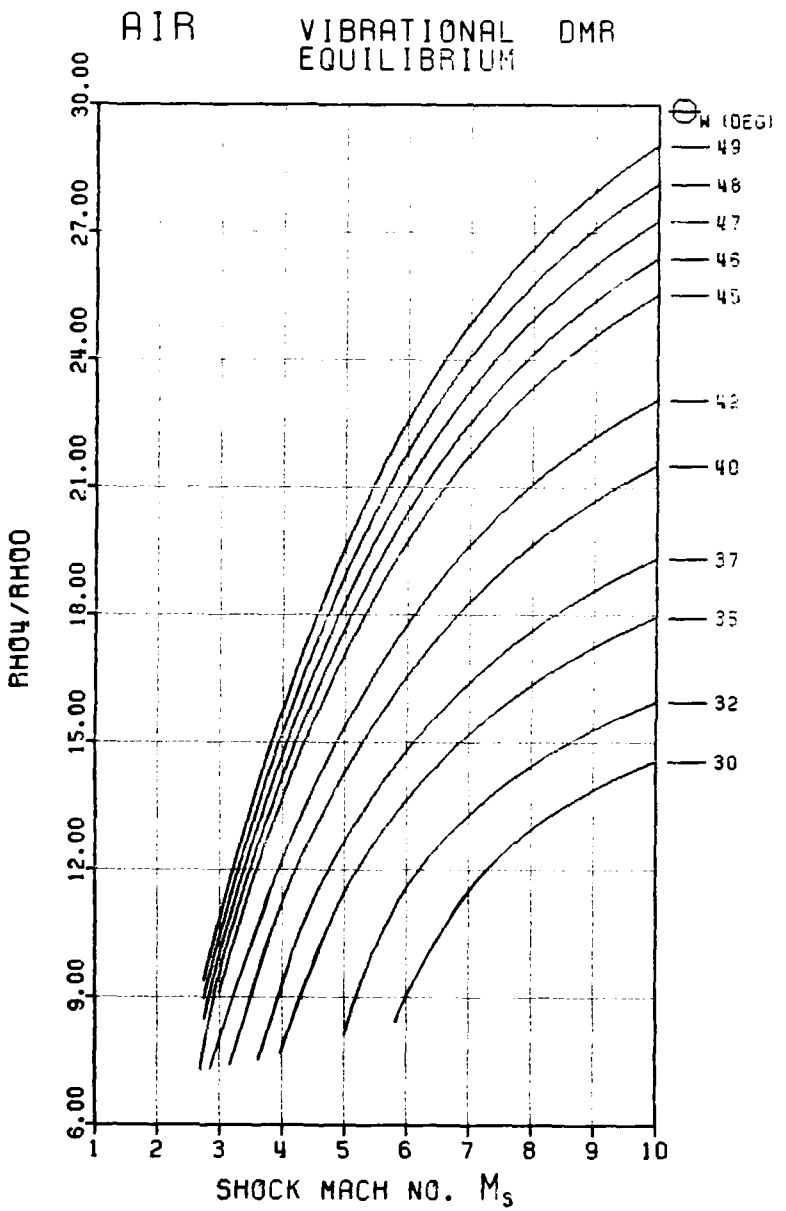
42
40
37
35
32
30


AIR
VIBRATIONAL EQUILIBRIUM
DMR
RHO4/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
30.00
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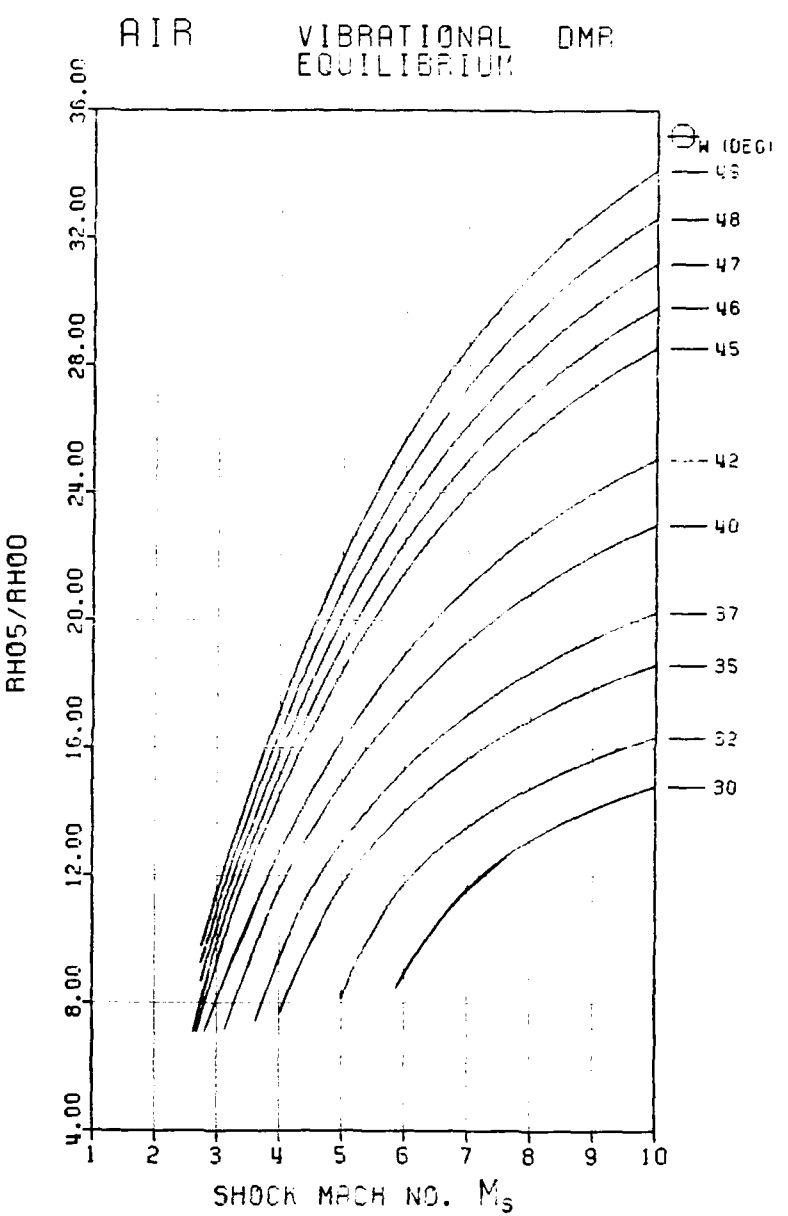
AIR
VIBRATIONAL EQUILIBRIUM
DMR
RHO5/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
48
47
46
45
42
40
37
35
32
30
4.00
8.00
12.00
16.00
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28.00
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36.00
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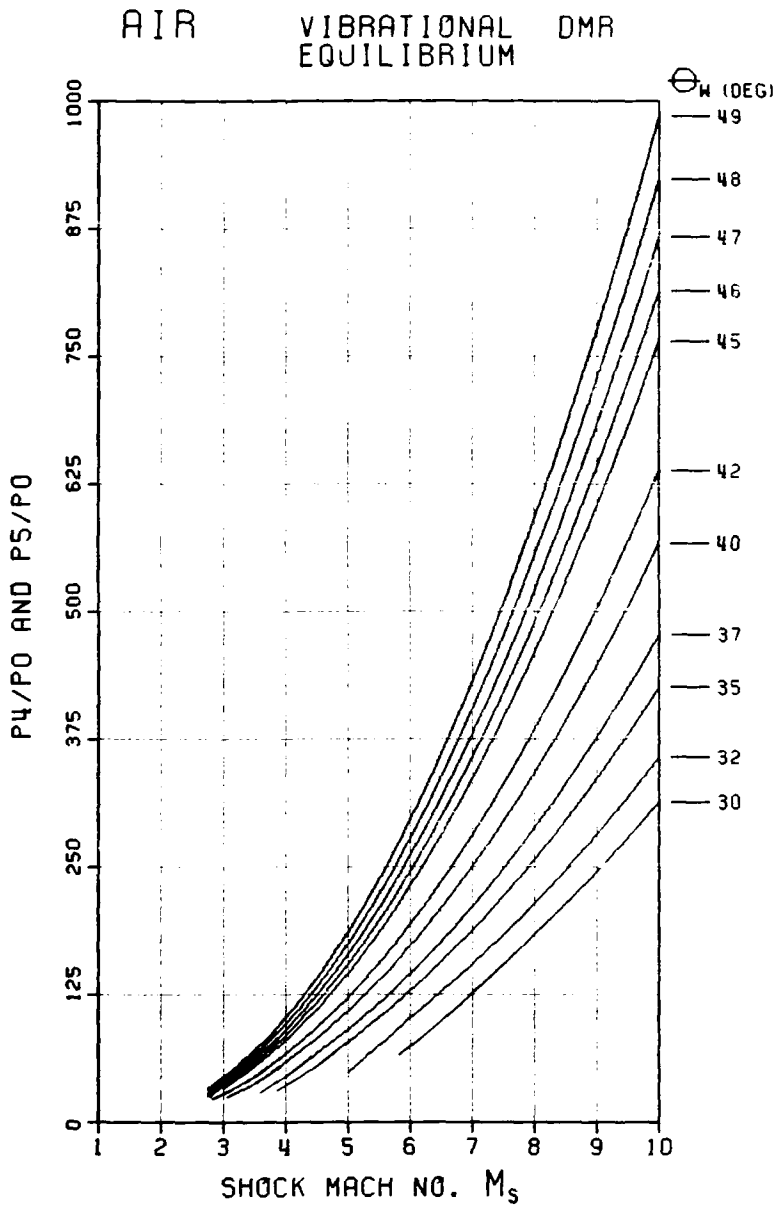
AIR
VIBRATIONAL EQUILIBRIUM
DMR
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
P4/P0 AND P5/P0
0
125
250
375
500
625
750
875
1000
1
2
3
4
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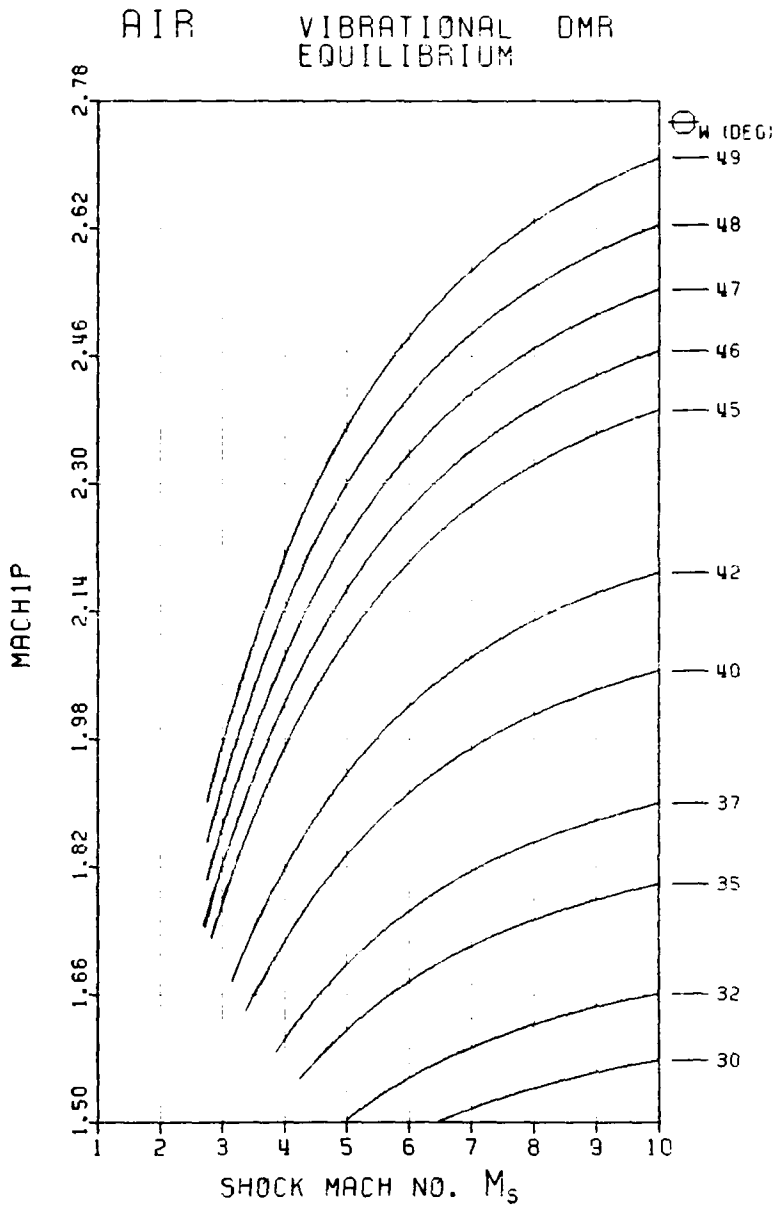
8
9
10
SHOCK MACH NO. M_S


AIR
VIBRATIONAL EQUILIBRIUM
DMR
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
MACH1P
1.50
1.66
1.82
1.98
2.14
2.30
2.46
2.62
2.78
1
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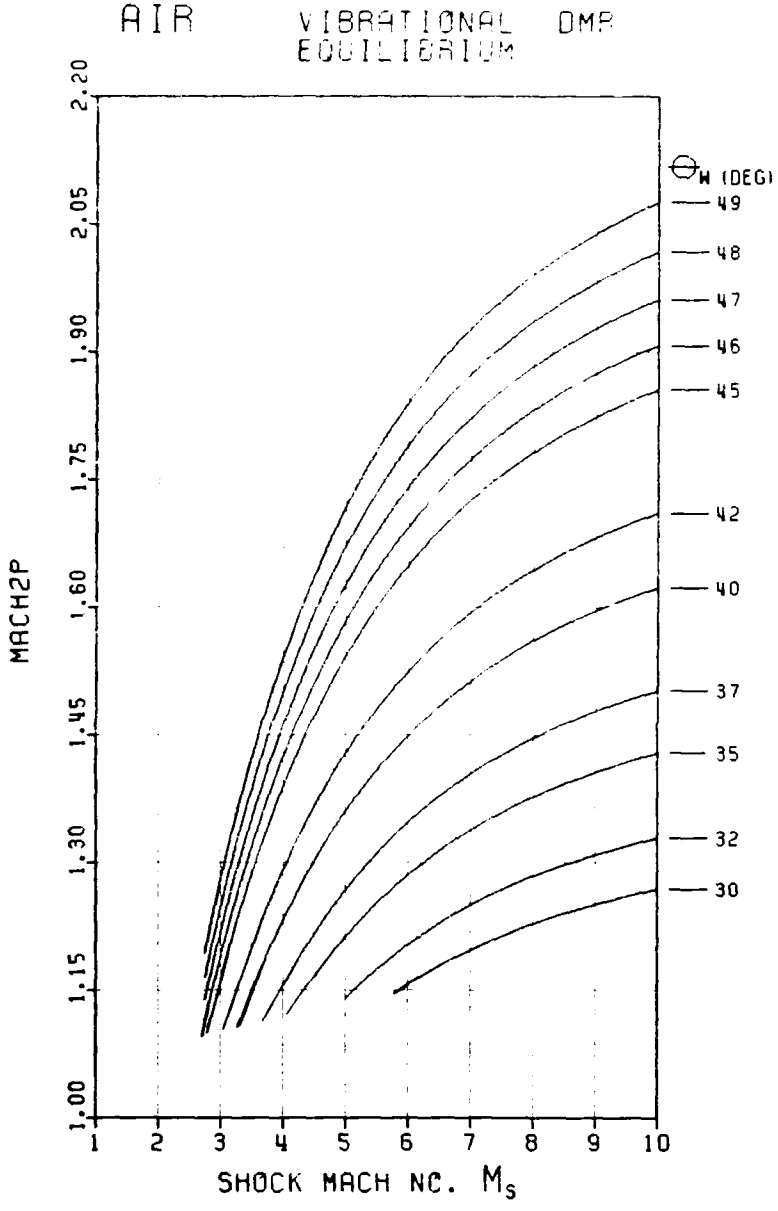
7
8
9
10
SHOCK MACH NO. M_S


AIR
VIBRATIONAL EQUILIBRIUM
DMR
MACH2P
SHOCK MACH NO. M_S
Θ_W (DEG)
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42
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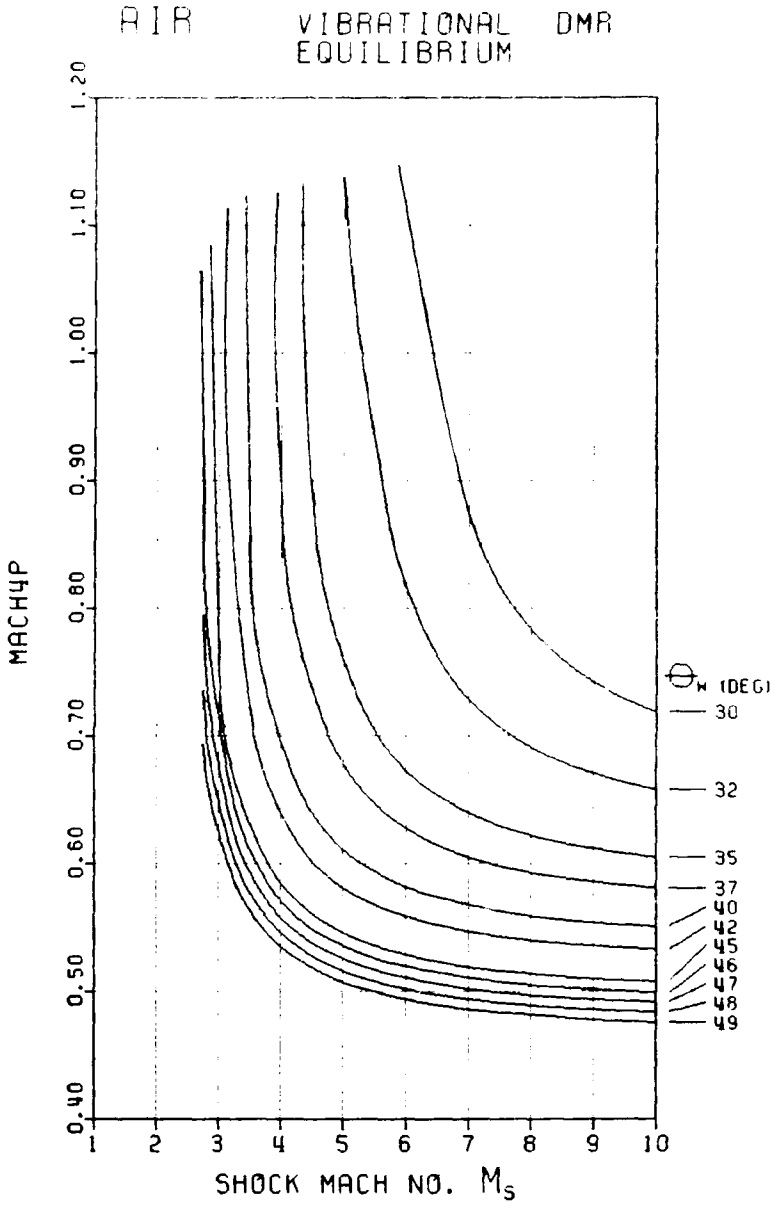
32
30


AIR
VIBRATIONAL EQUILIBRIUM
DMR
MACH4P
SHOCK MACH NO. M_S
Θ_W (DEG)
30
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42
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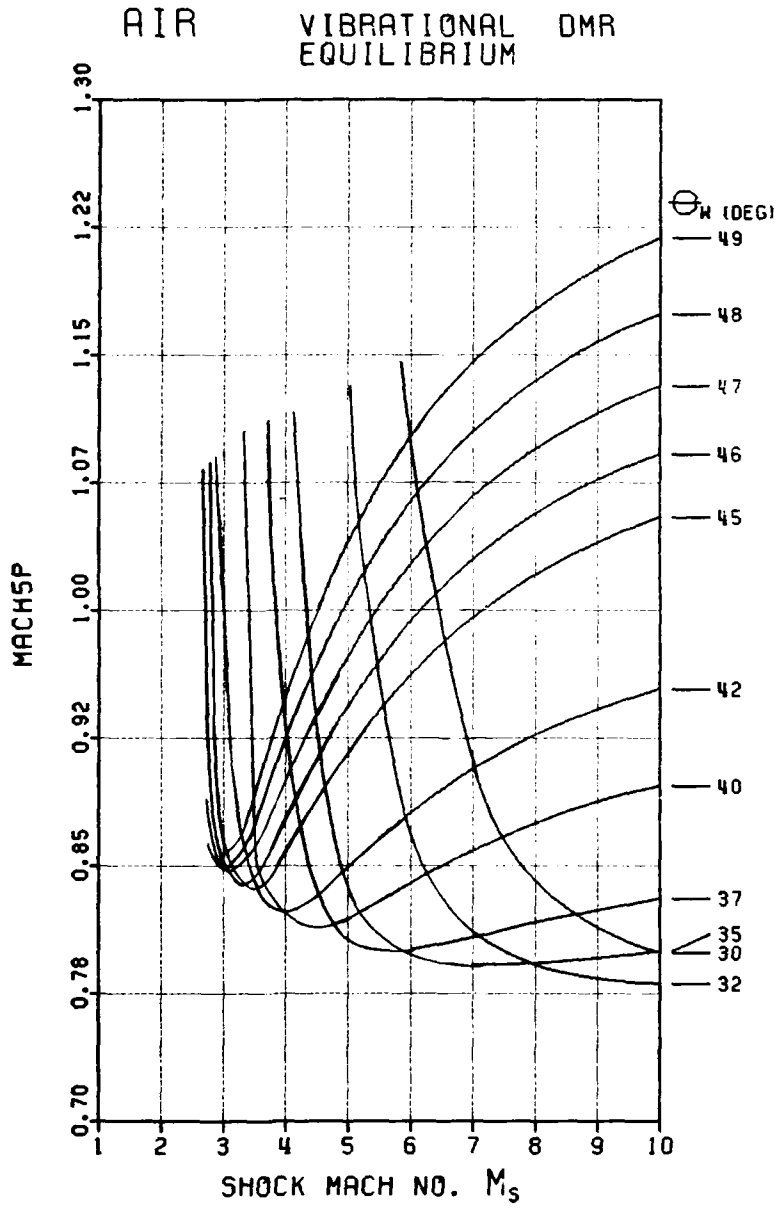
48
49


AIR
VIBRATIONAL EQUILIBRIUM
DMR
MACHSP
1.30
1.22
1.15
1.07
1.00
0.92
0.85
0.78
0.70
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
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48
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46
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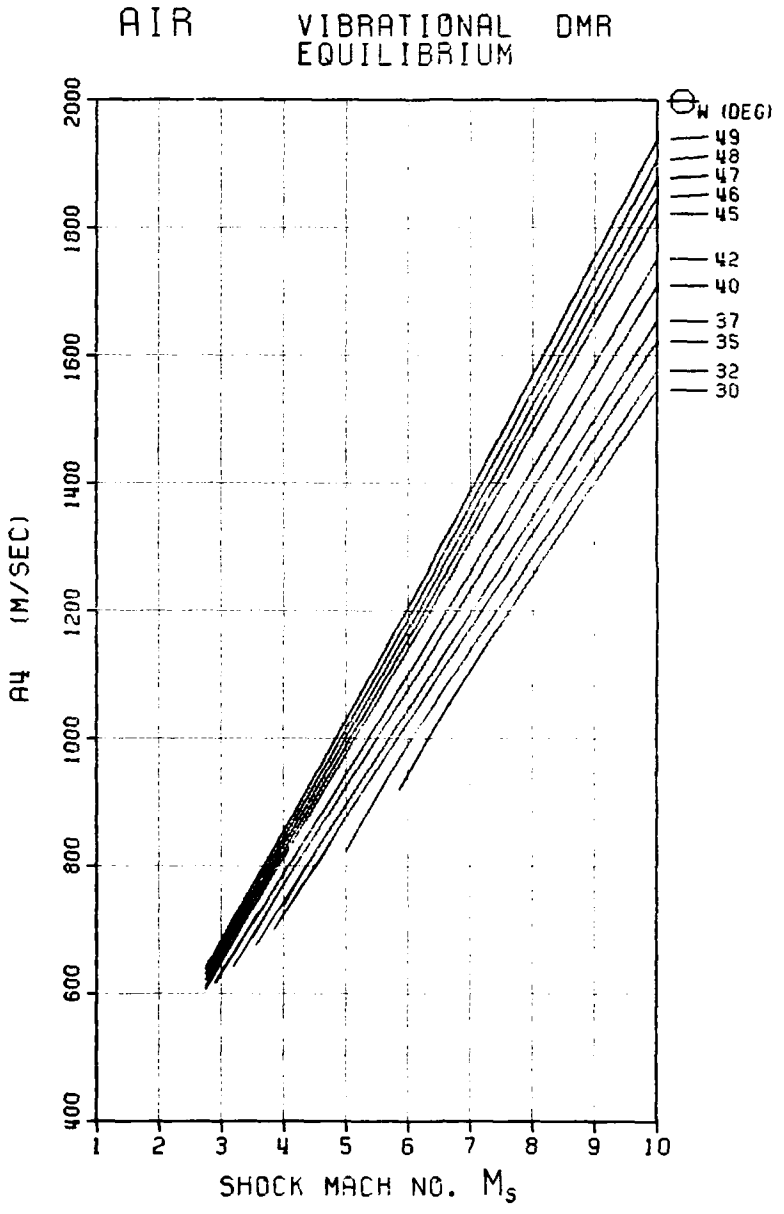
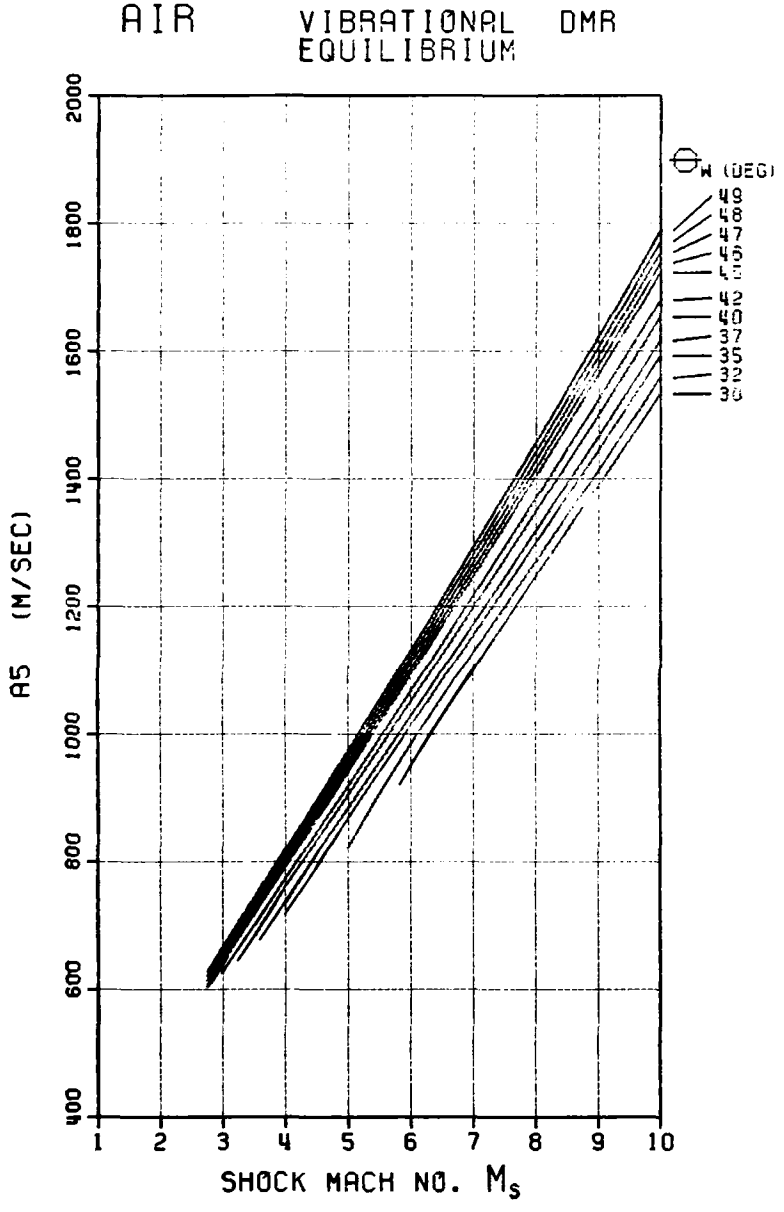
32


AIR
VIBRATIONAL EQUILIBRIUM
DMR
A4 (M/SEC)
2000
1800
1600
1400
1200
1000
800
600
400
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30


AIR
VIBRATIONAL EQUILIBRIUM
DMR
A5 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
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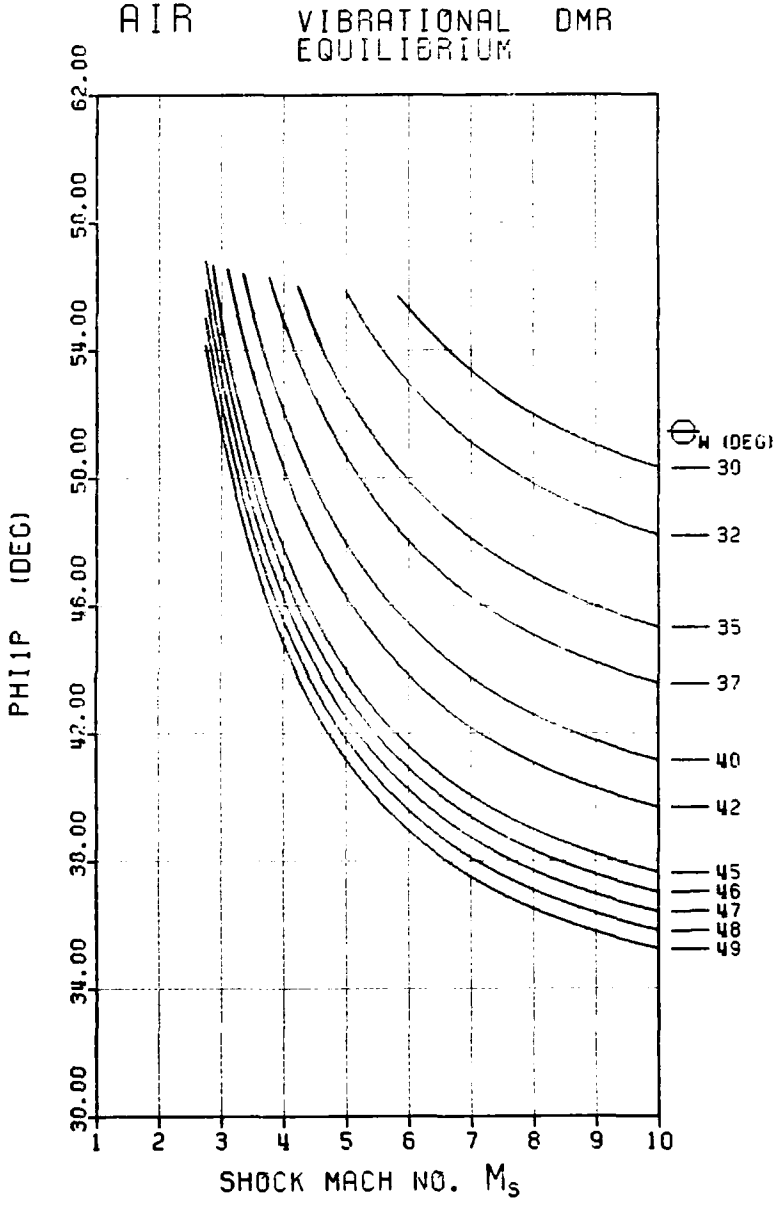
AIR
VIBRATIONAL EQUILIBRIUM
DMR
PHI1P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
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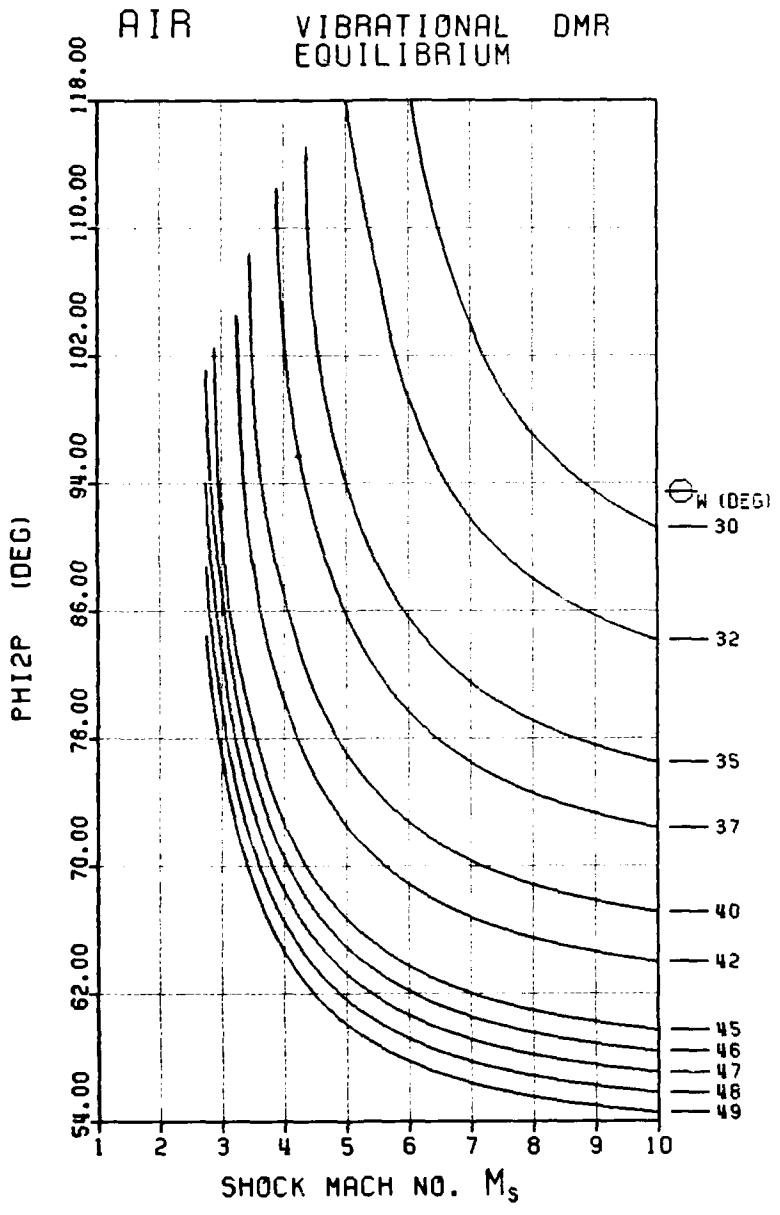
48
49


AIR
VIBRATIONAL EQUILIBRIUM
DMR
PHI2P (DEG)
118.00
110.00
102.00
94.00
86.00
78.00
70.00
62.00
54.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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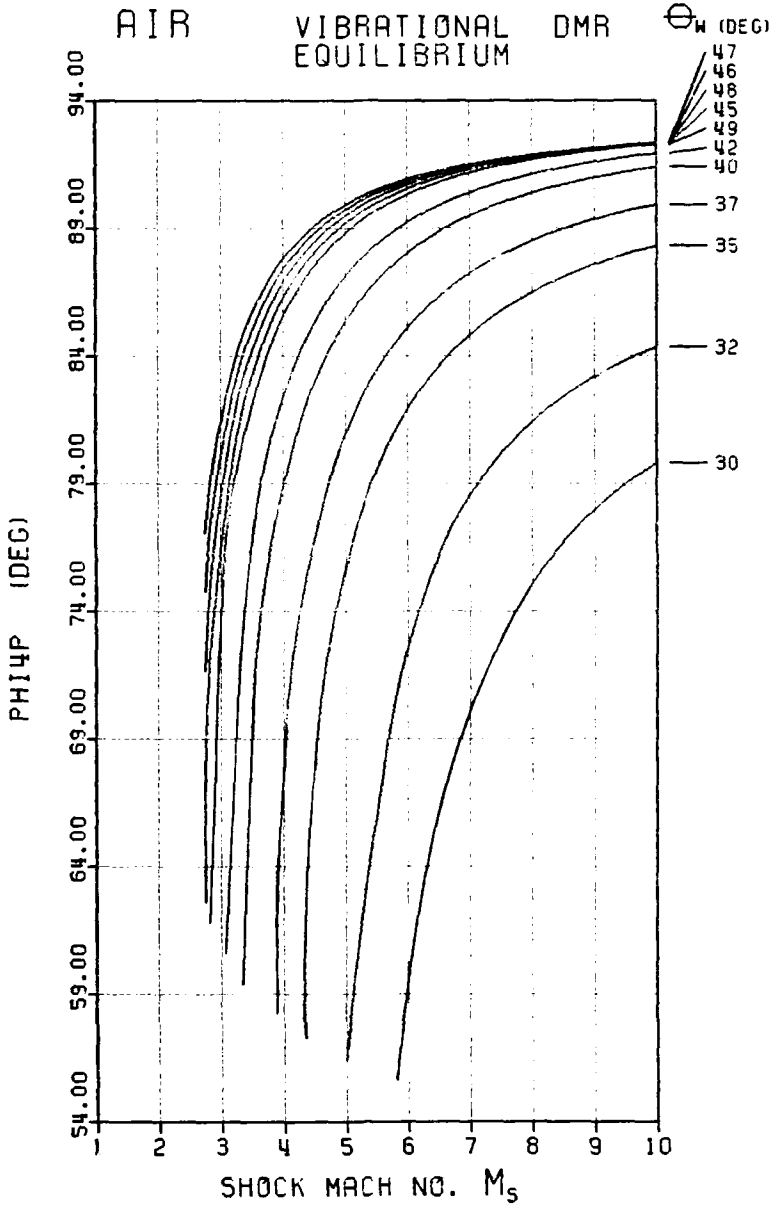
48
49


AIR
VIBRATIONAL EQUILIBRIUM
DMR
PHI4P (DEG)
94.00
89.00
84.00
79.00
74.00
69.00
64.00
59.00
54.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
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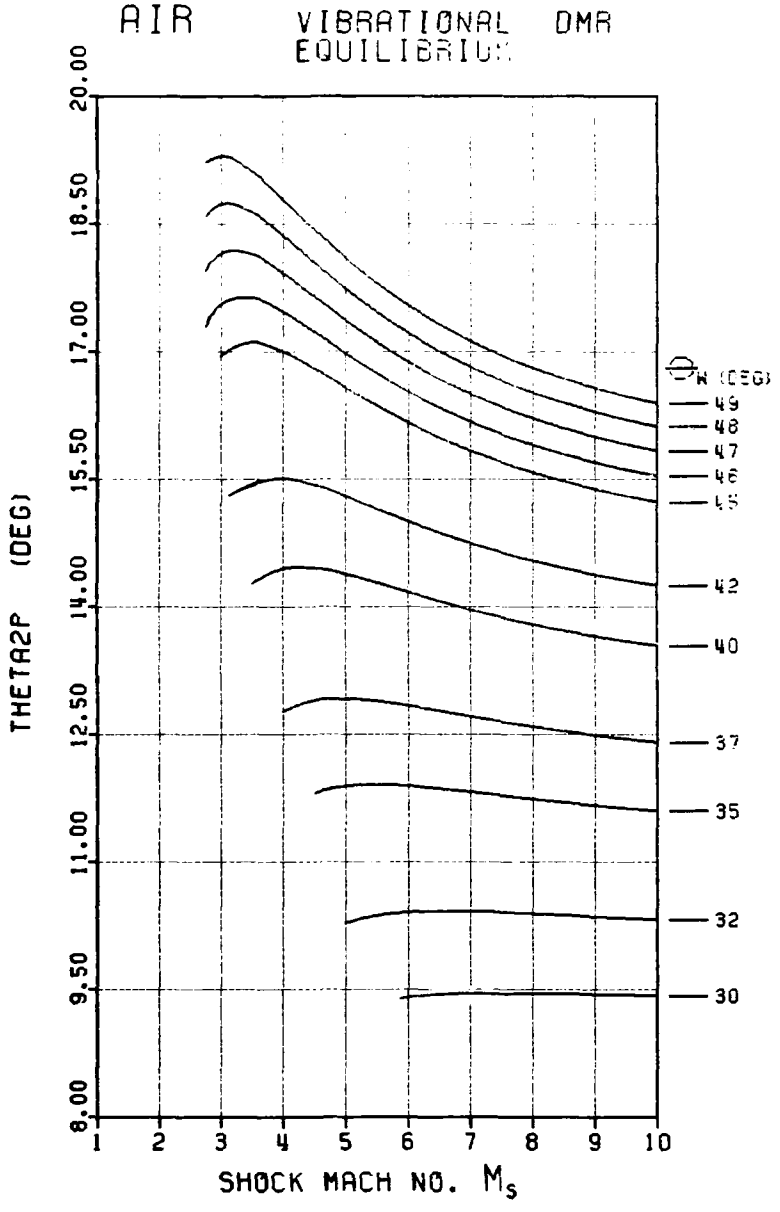
AIR
VIBRATIONAL EQUILIBRIUM
DMR
THETA2P (DEG)
SHOCK MACH NO. M_s
Θ_w (DEG)
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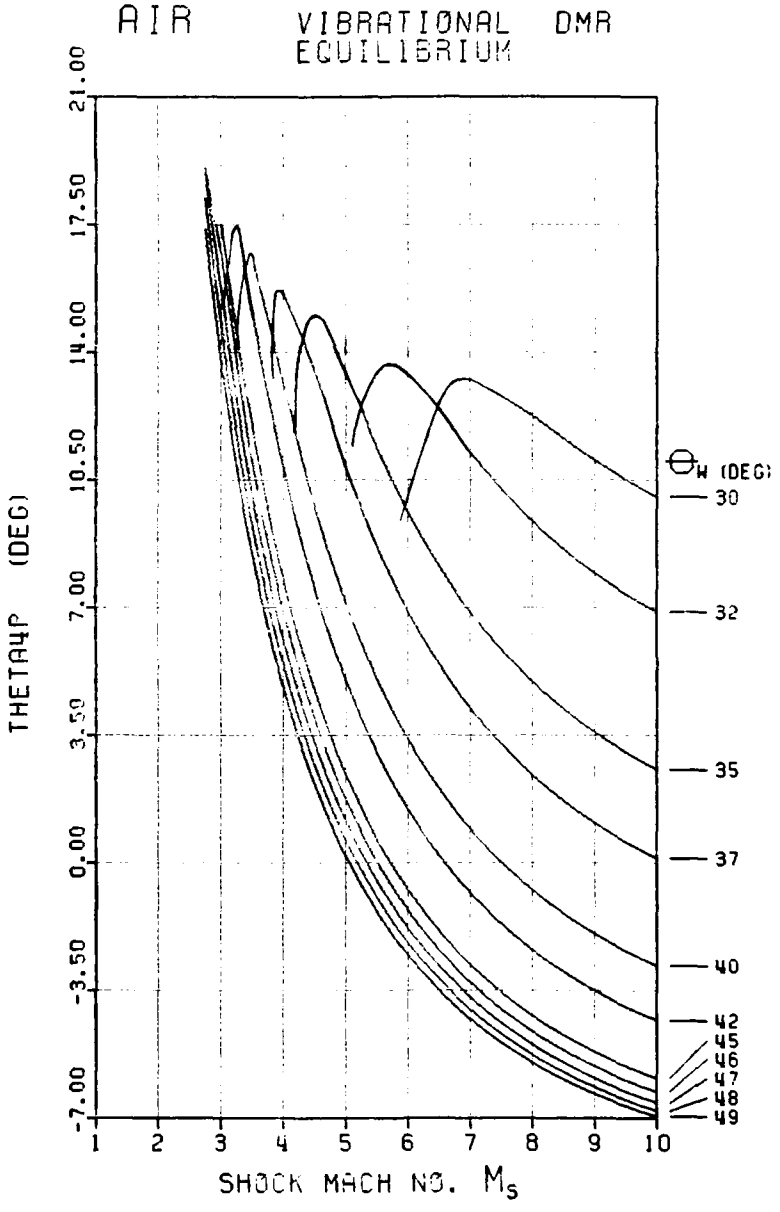
AIR
VIBRATIONAL EQUILIBRIUM
DMR
THETA4P (DEG)
SHOCK MACH NO. M_s
Θ_w (DEG)
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48
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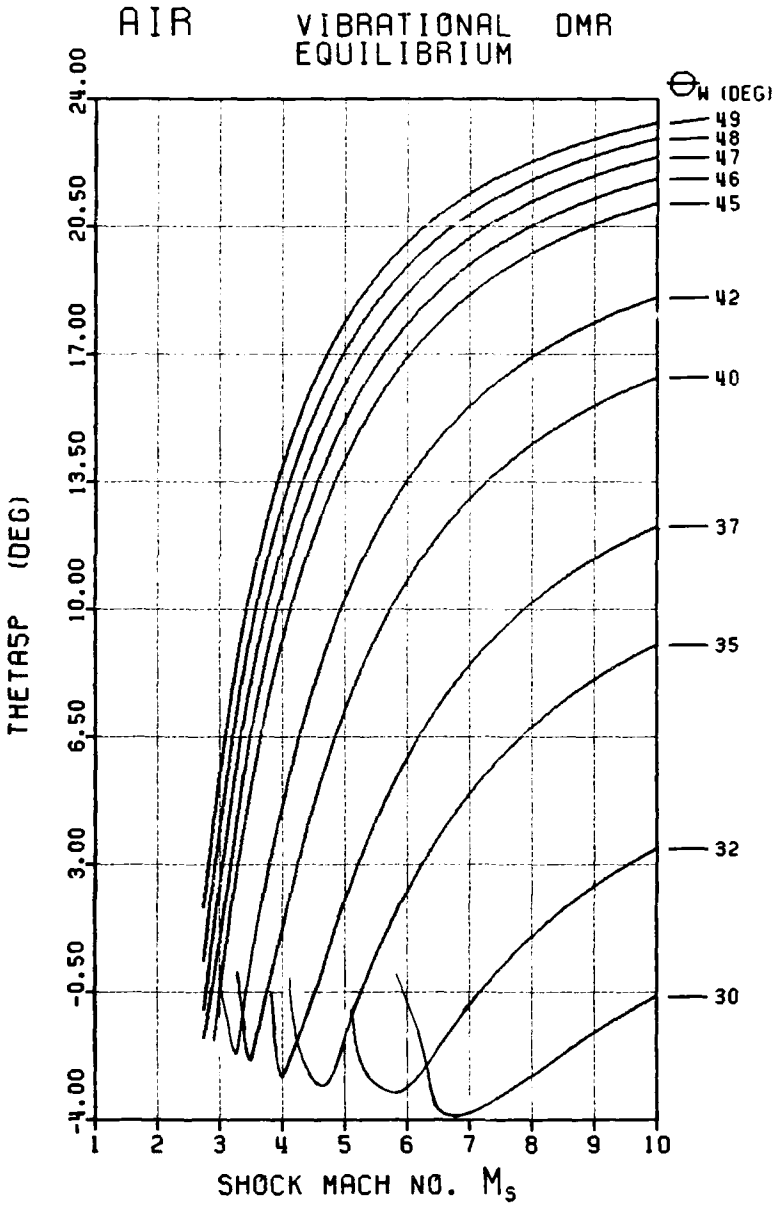
AIR
VIBRATIONAL EQUILIBRIUM
DMR
THETASP (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
24.00
20.50
17.00
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-4.00
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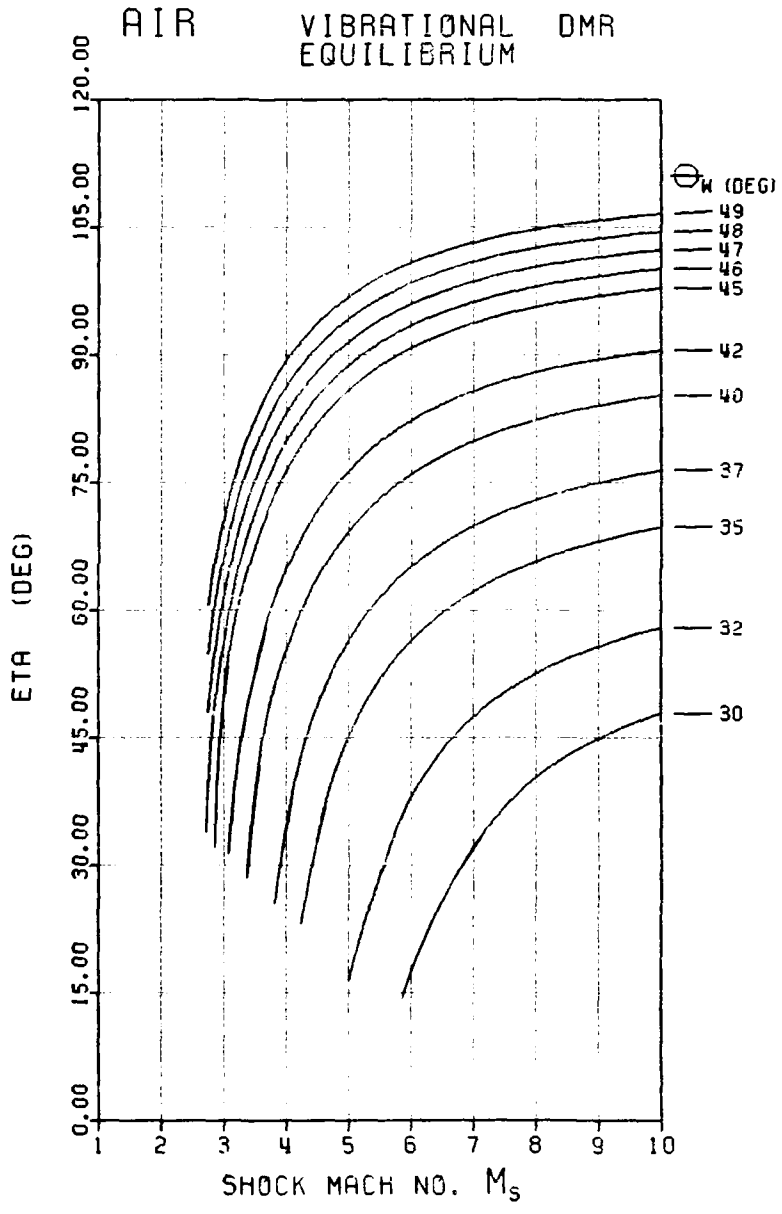
AIR
VIBRATIONAL EQUILIBRIUM
DMR
ETA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
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48
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46
45
42
40
37
35
32
30
120.00
105.00
90.00
75.00
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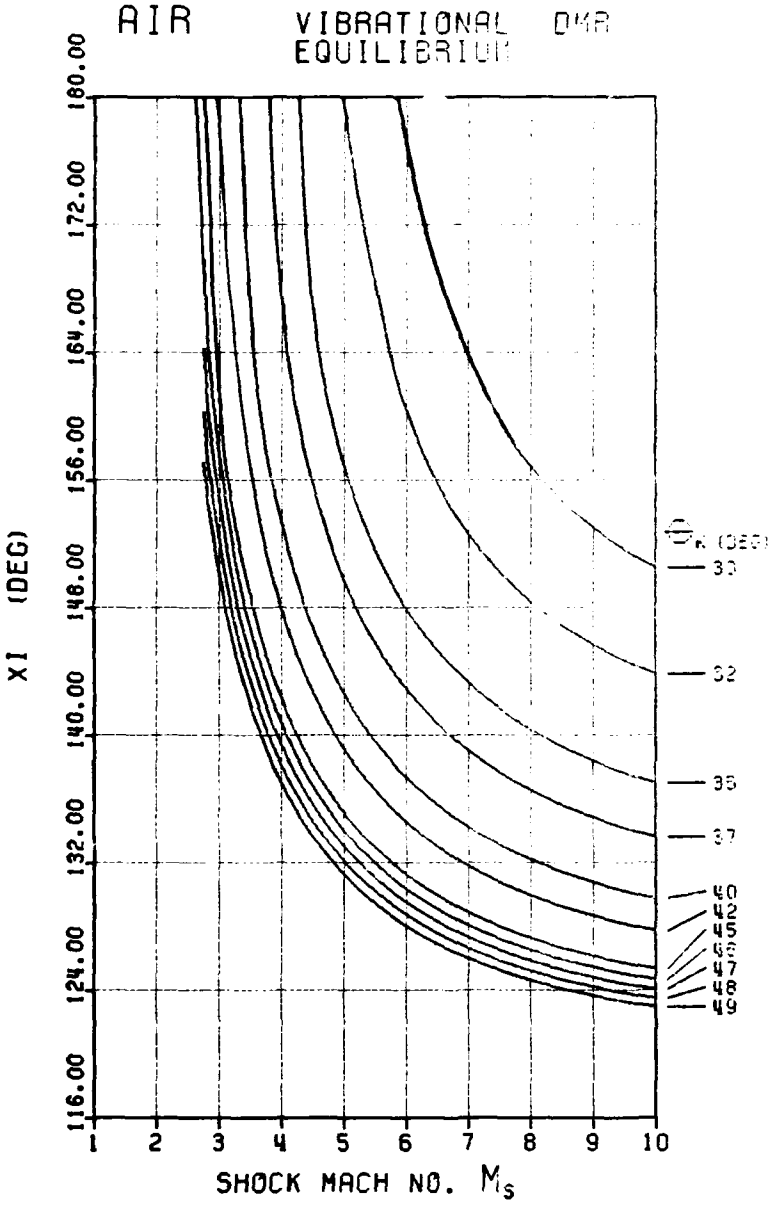
AIR
VIBRATIONAL
EQUILIBRIUM
180.00
172.00
164.00
156.00
148.00
140.00
132.00
124.00
116.00
XI (DEG)
1
2
3
4
5
6
7
8
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10
SHOCK MACH NO. M_S
Θ_R (DEG)
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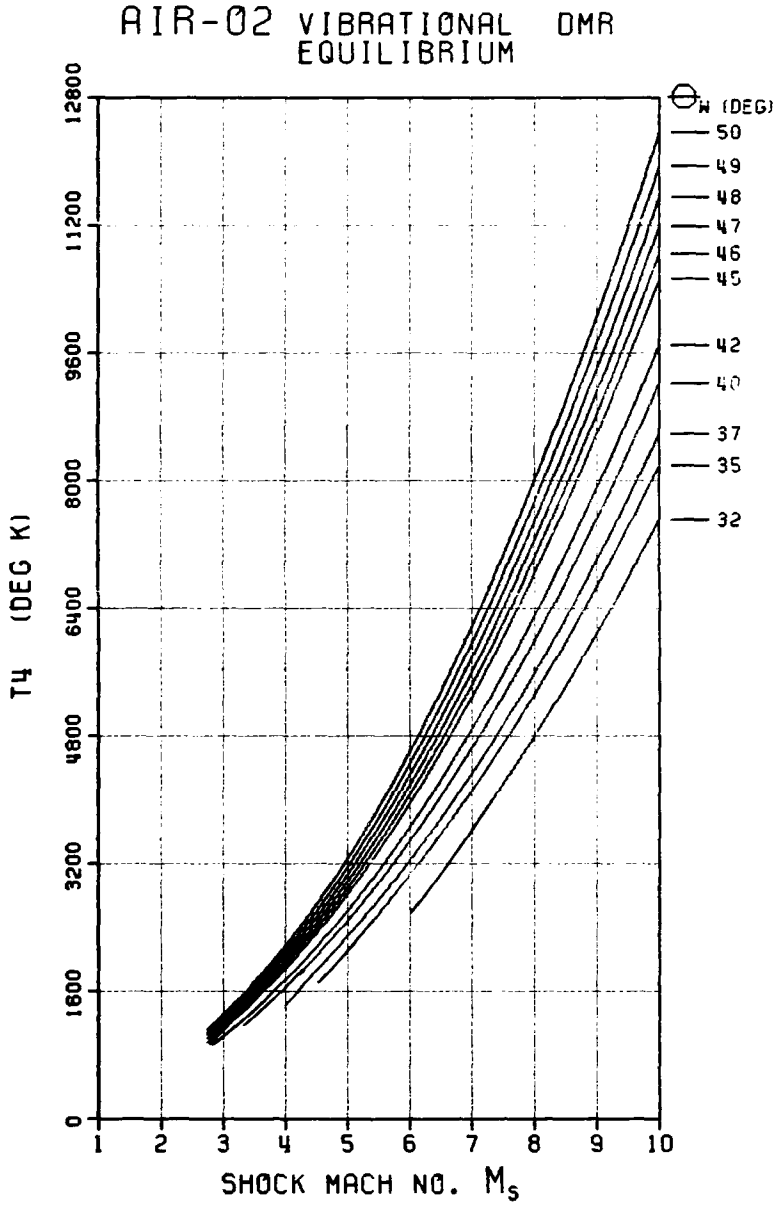
49


AIR-02 VIBRATIONAL EQUILIBRIUM DMR
T4 (DEG K)
SHOCK MACH NO. M_S
Θ_W (DEG)
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48
47
46
45
42
40
37
35
32
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1600
3200
4800
6400
8000
9600
11200
12800
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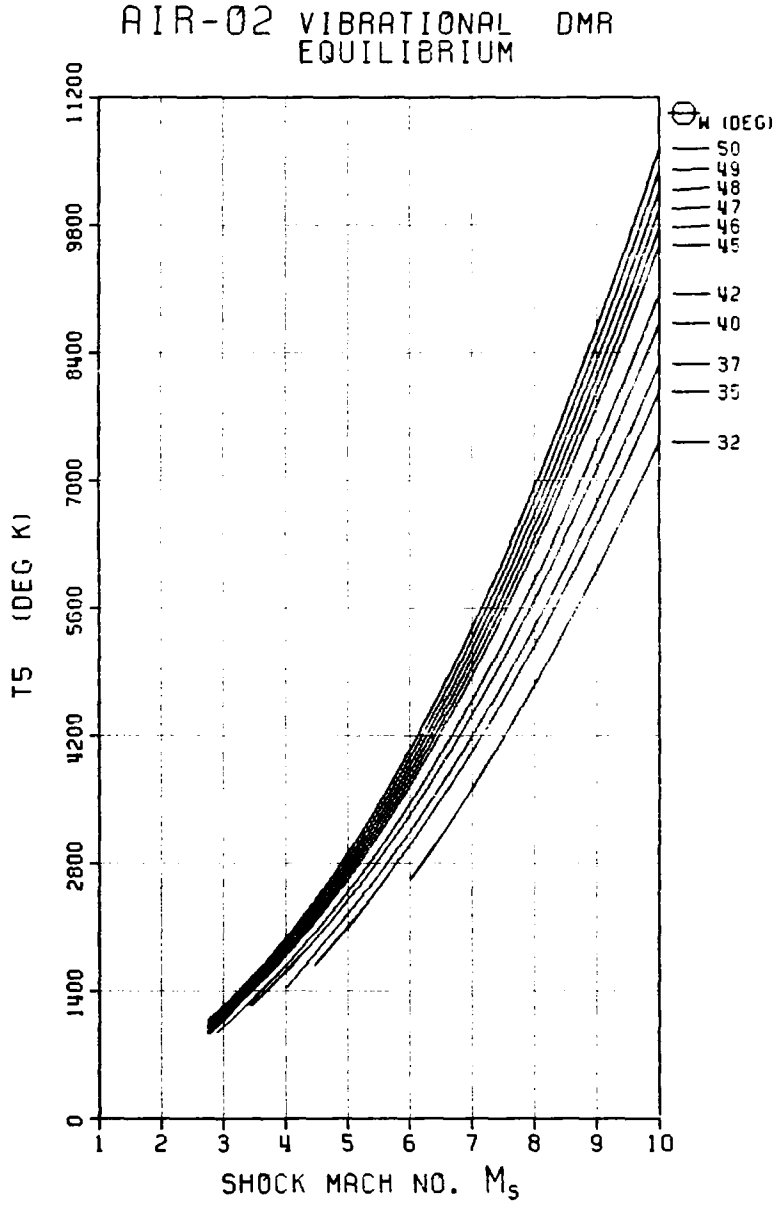
AIR-02 VIBRATIONAL EQUILIBRIUM DMR
T5 (DEG K)
SHOCK MACH NO. M_S
Θ_W (DEG)
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46
45
42
40
37
35
32
0
1400
2800
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5600
7000
8400
9800
11200
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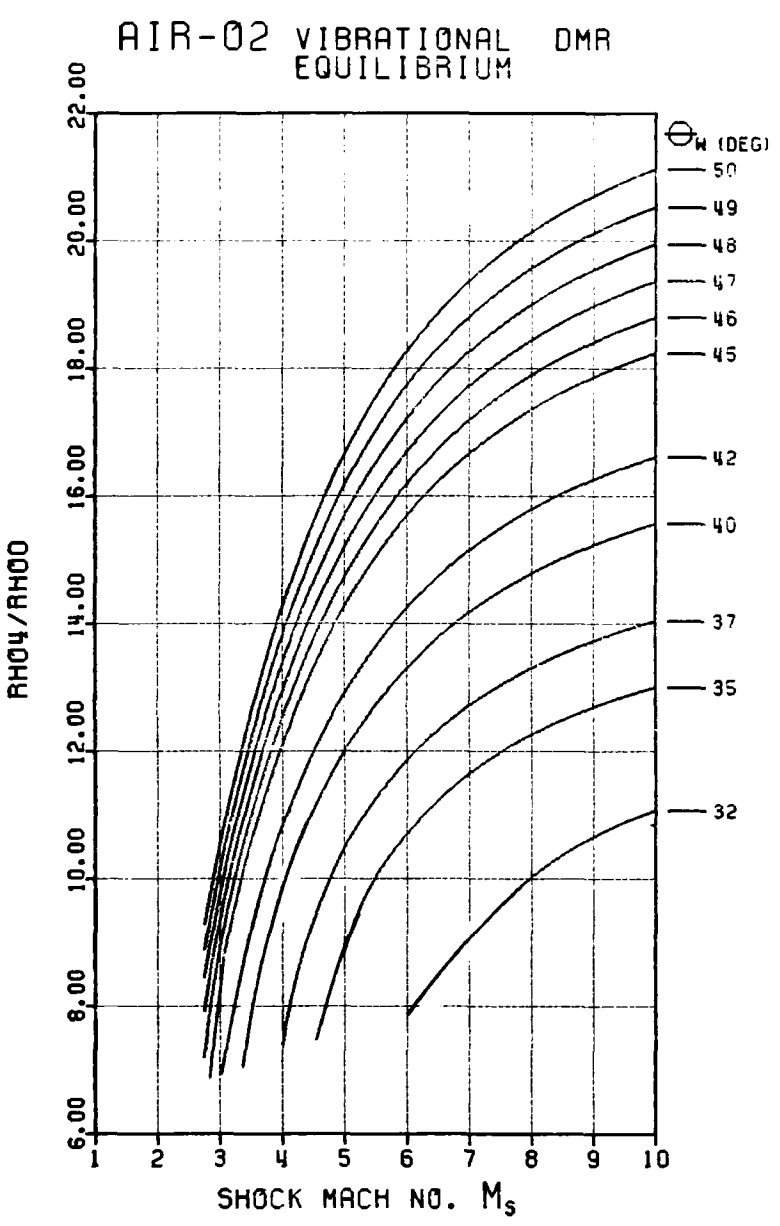
AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
RHO4/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
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37
35
32
22.00
20.00
18.00
16.00
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12.00
10.00
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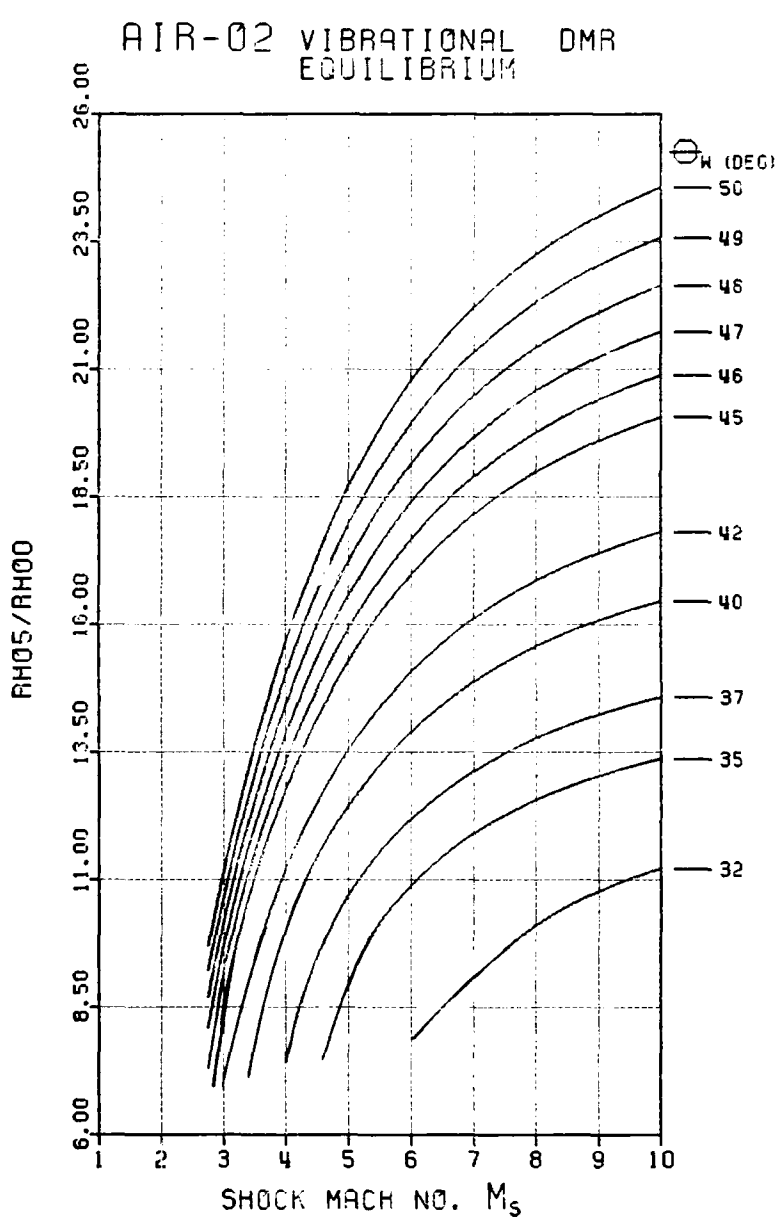
AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
RHO5/RHOO
SHOCK MACH NO. M_S
Θ_W (DEG)
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49
46
47
46
45
42
40
37
35
32
26.00
23.50
21.00
18.50
16.00
13.50
11.00
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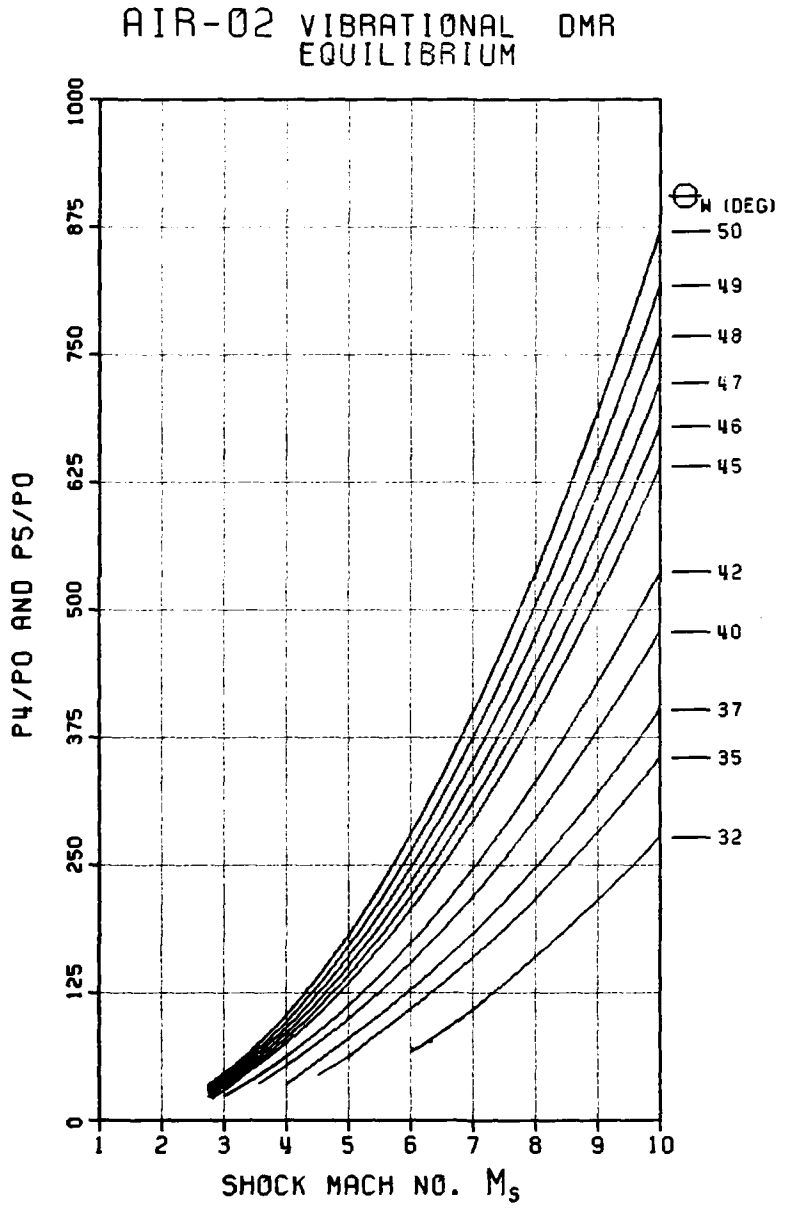
AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
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47
46
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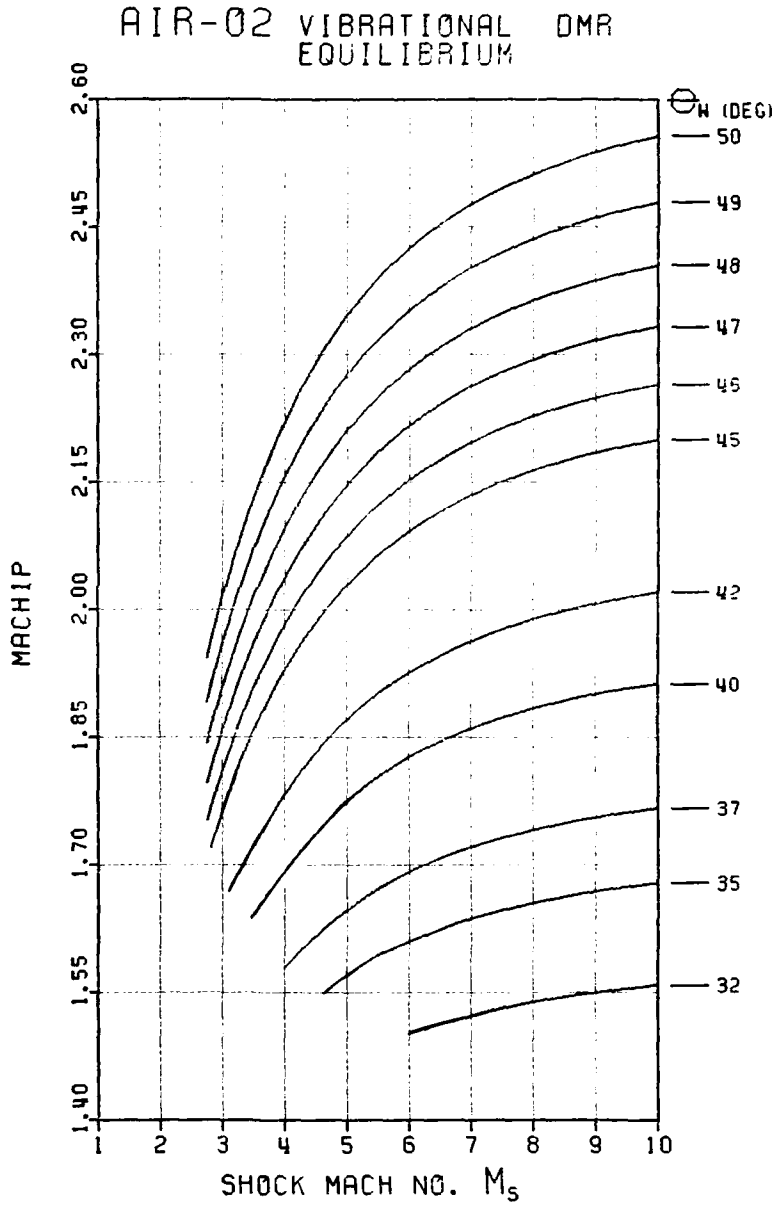
35
32


AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
MACHIP
SHOCK MACH NO. M_S
Θ_W (DEG)
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49
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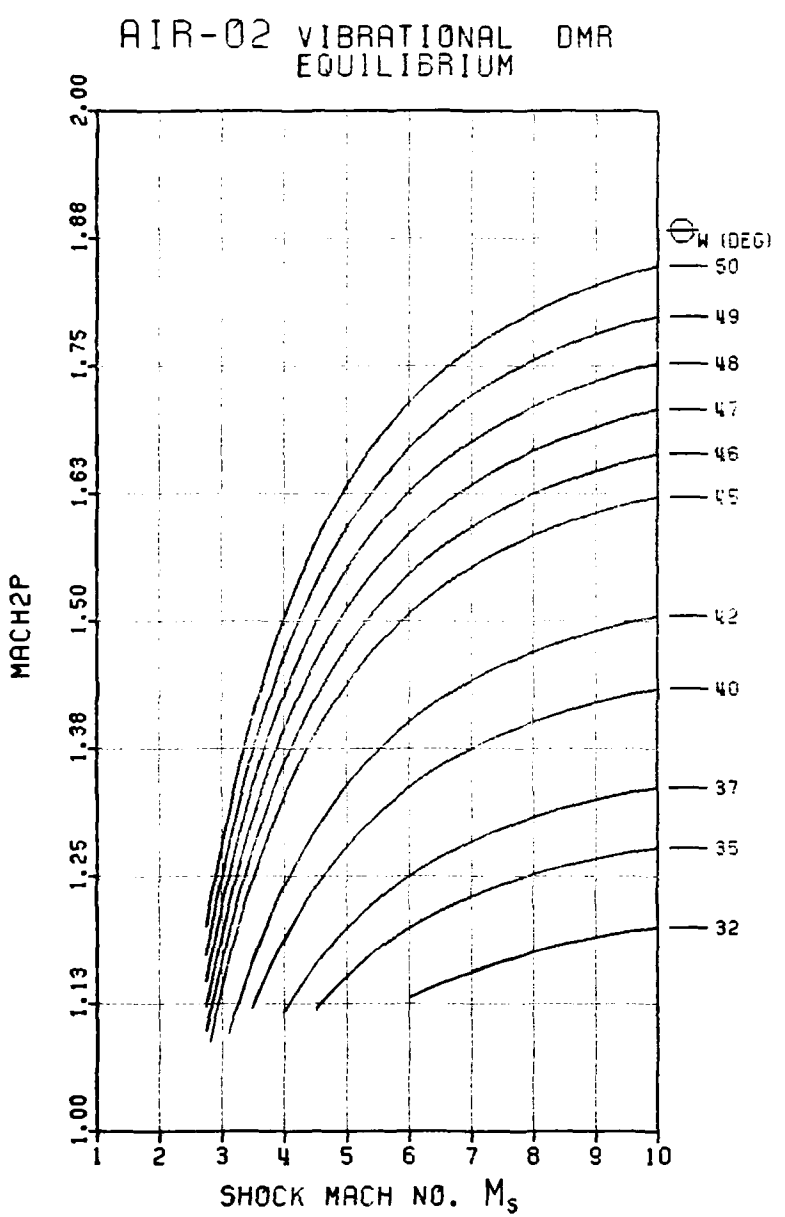
35
32


AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
MACH2P
SHOCK MACH NO. M_s
Θ_w (DEG)
50
49
48
47
46
45
42
40
37
35
32
1.00
1.13
1.25
1.38
1.50
1.63
1.75
1.88
2.00
1
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3
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9
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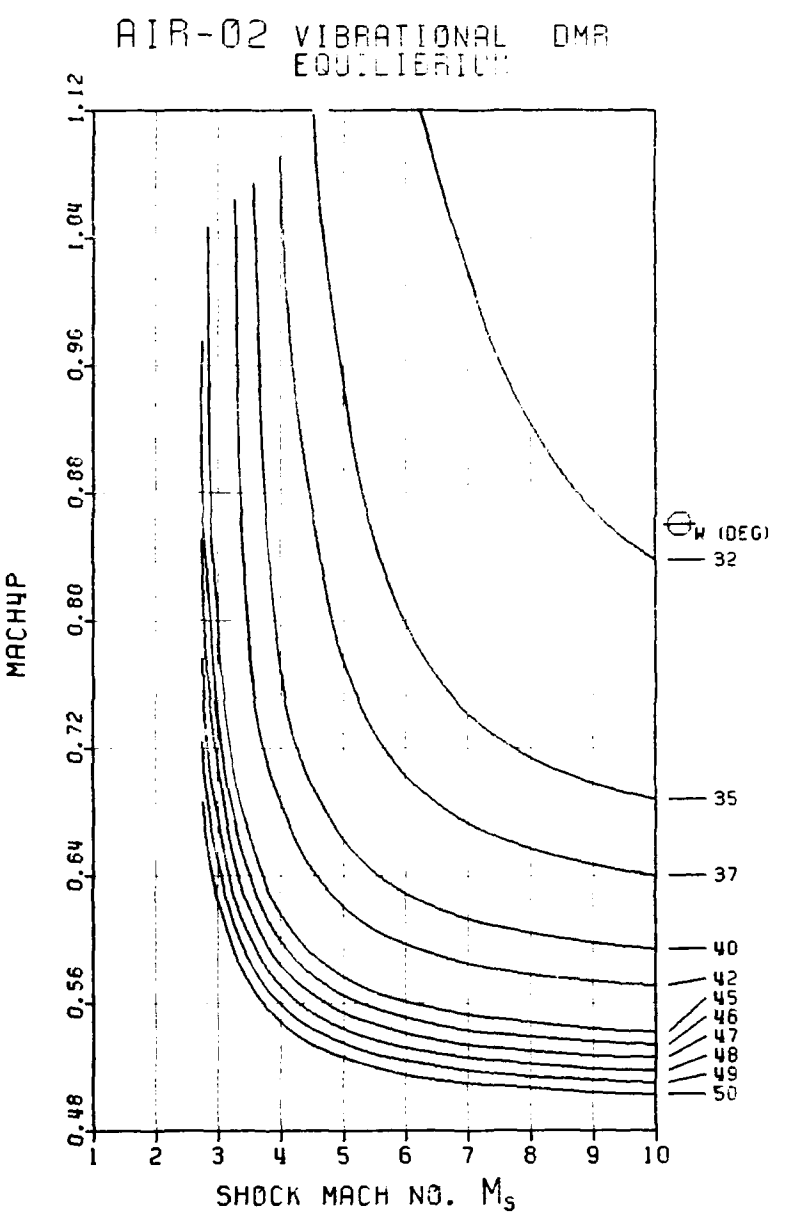
AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
MACH4P
SHOCK MACH NO. M_s
Θ_w (DEG)
32
35
37
40
42
45
46
47
48
49
50
0.48
0.56
0.64
0.72
0.80
0.88
0.96
1.04
1.12
1
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3
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9
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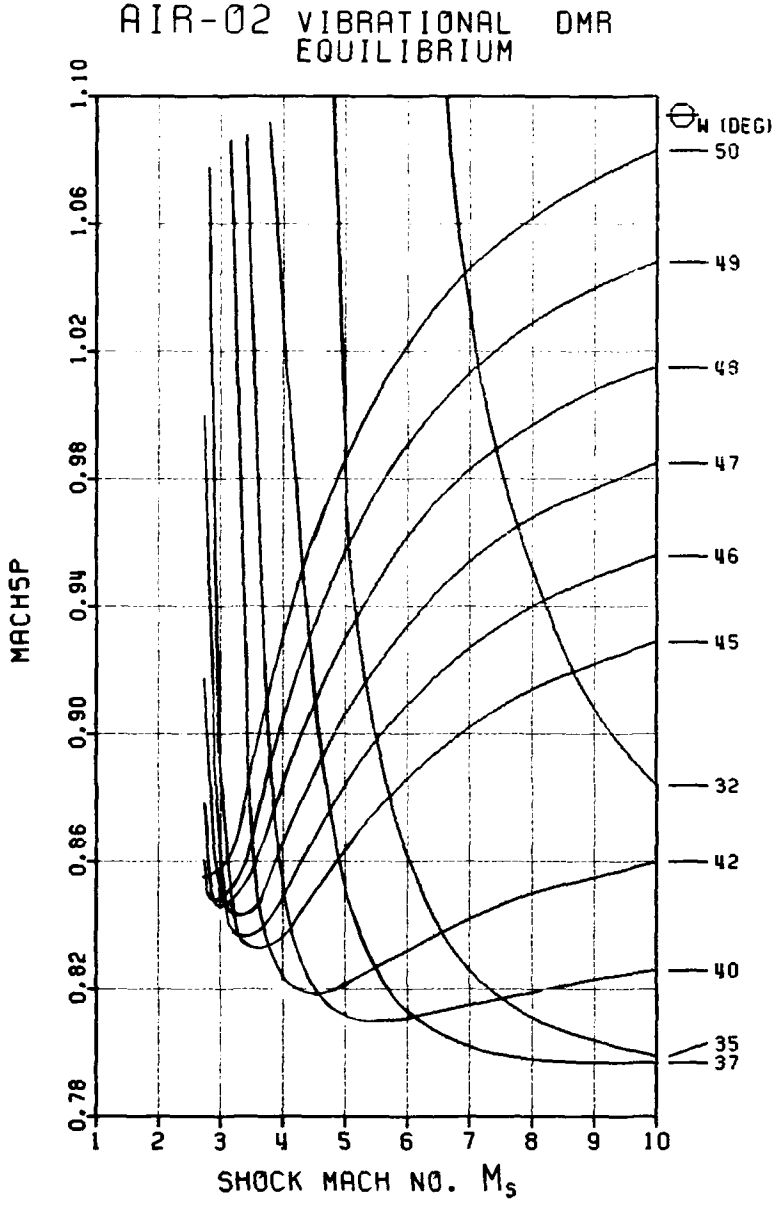
AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
MACHSP
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
32
42
40
35
37
0.78
0.82
0.86
0.90
0.94
0.98
1.02
1.06
1.10
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3
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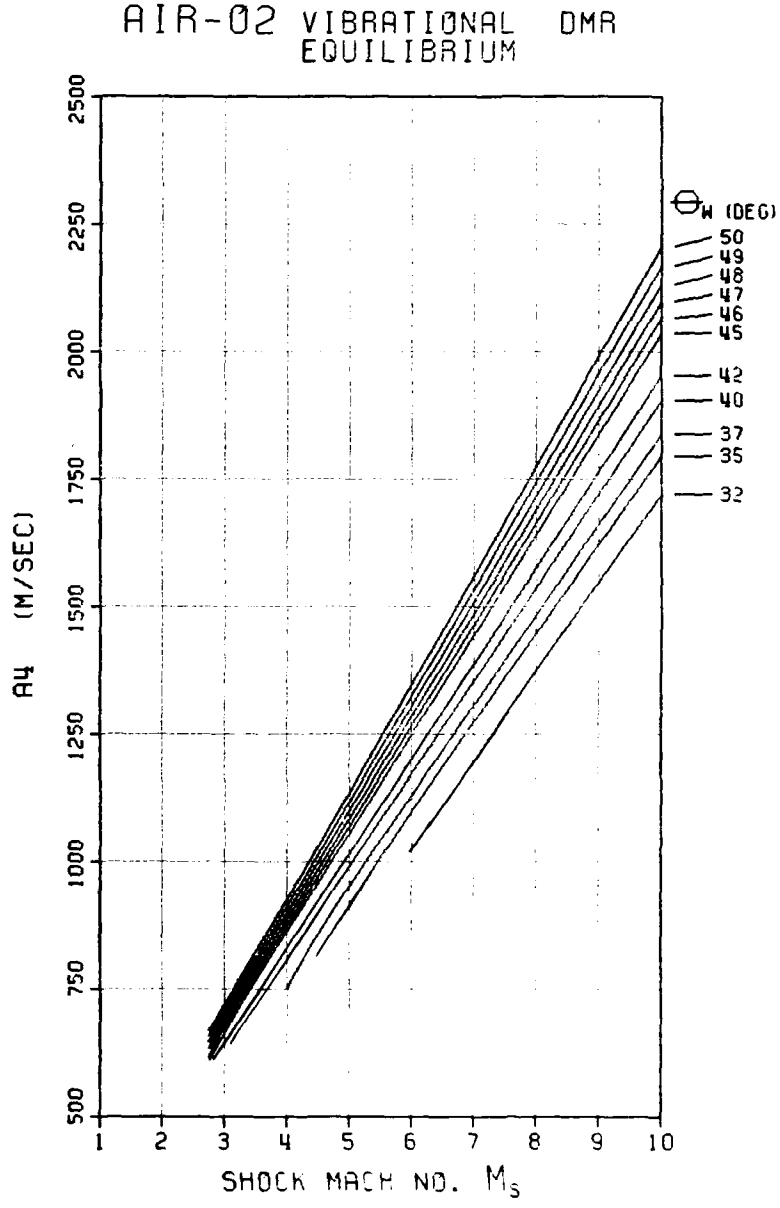
9
10


AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
500
750
1000
1250
1500
1750
2000
2250
2500
1
2
3
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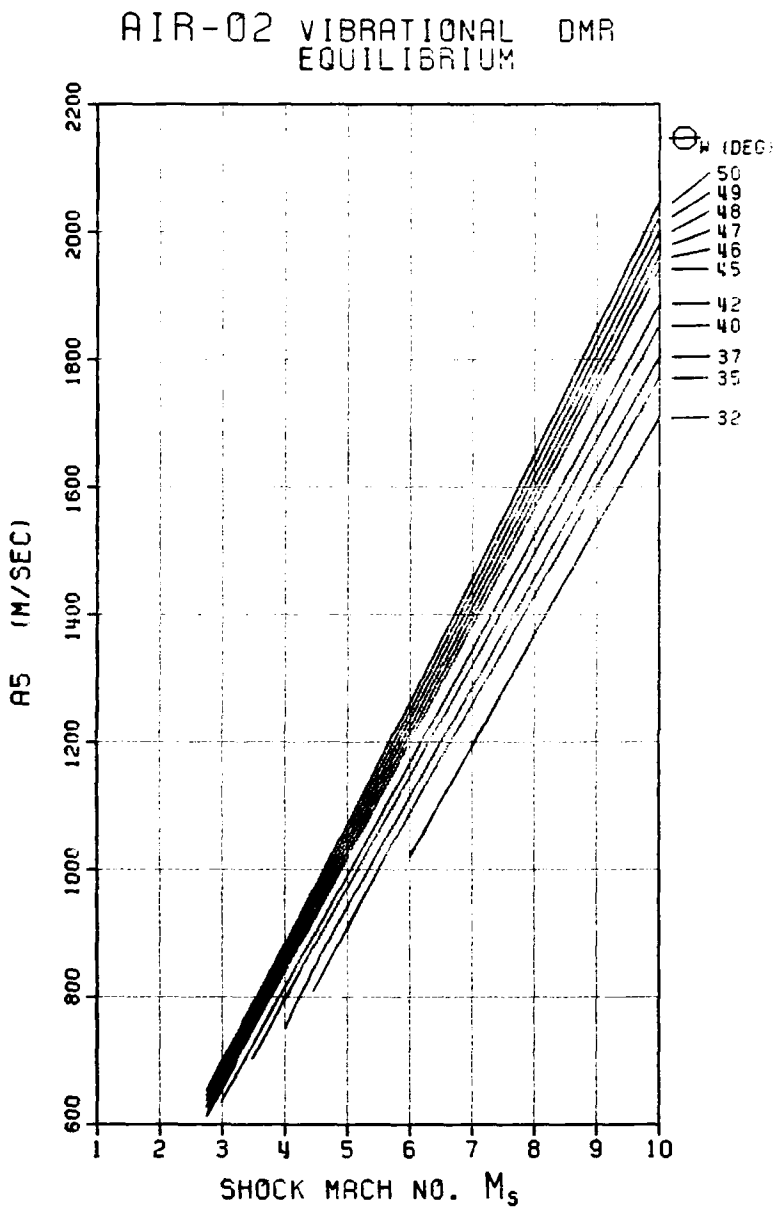
8
9
10


AIR-02 VIBRATIONAL DMR EQUILIBRIUM
A5 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
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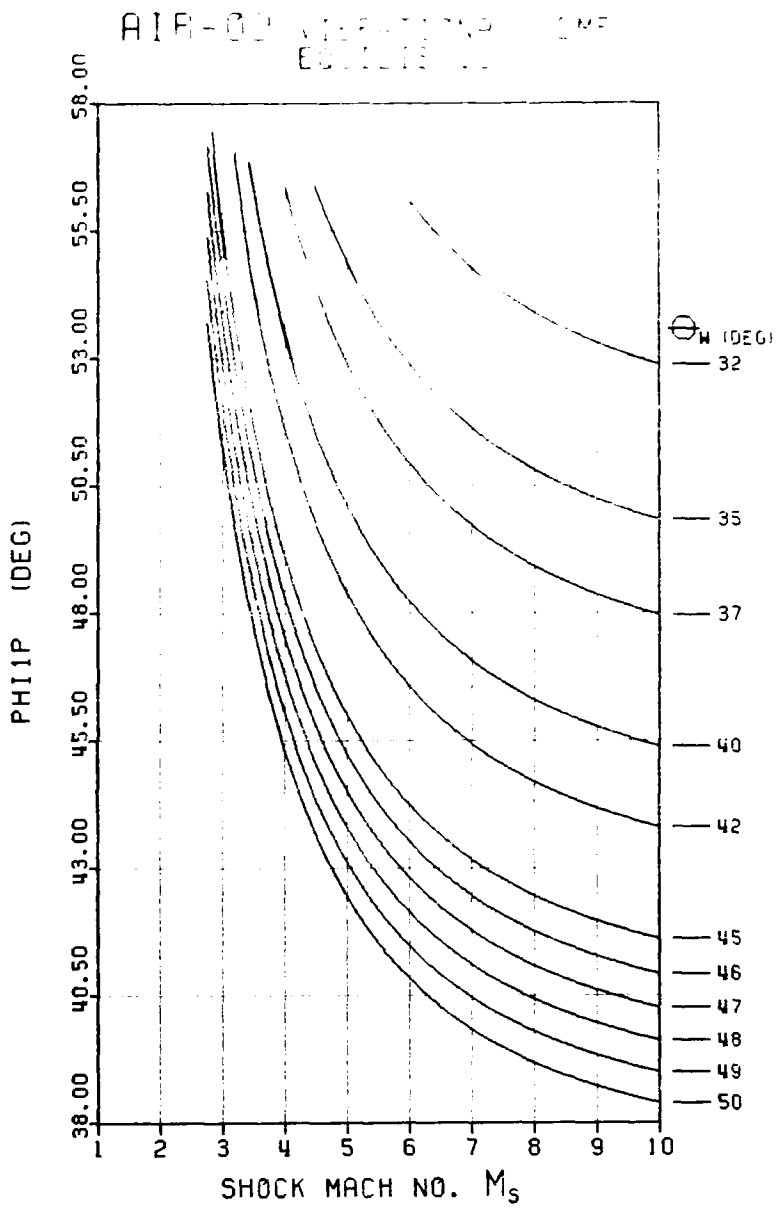
PHI1P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
37
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42
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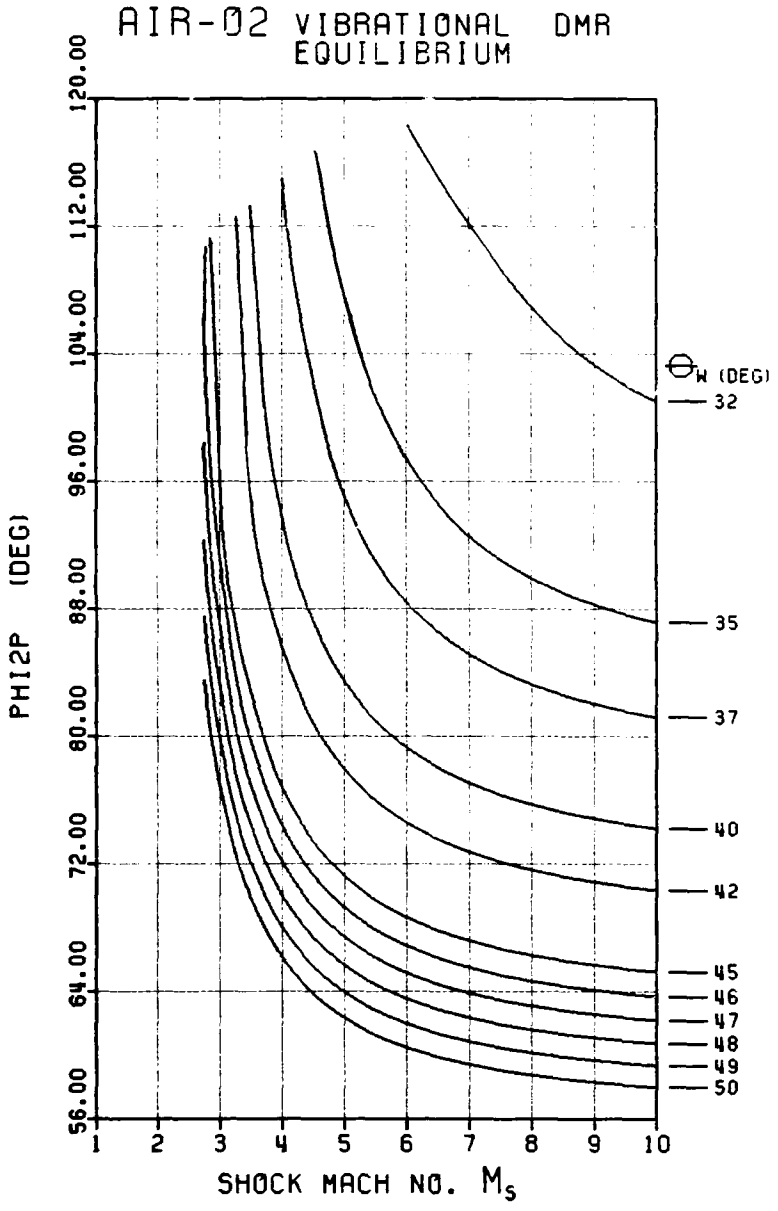
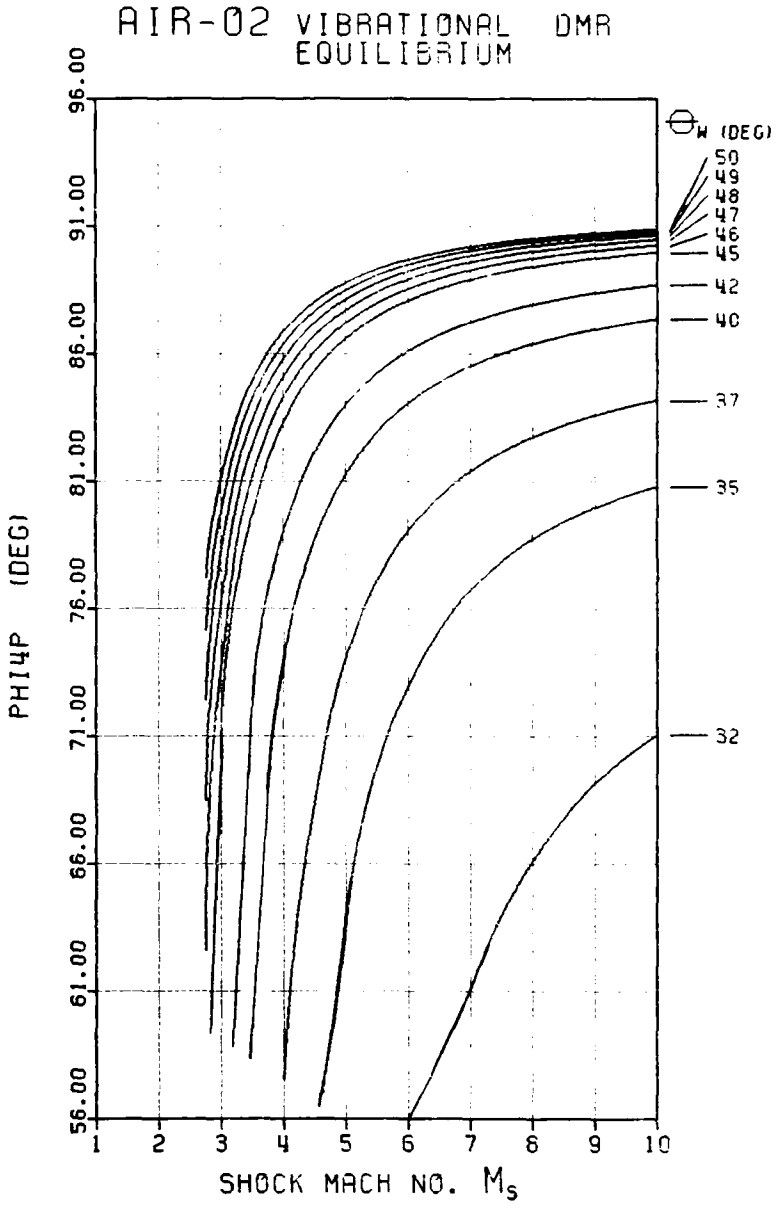
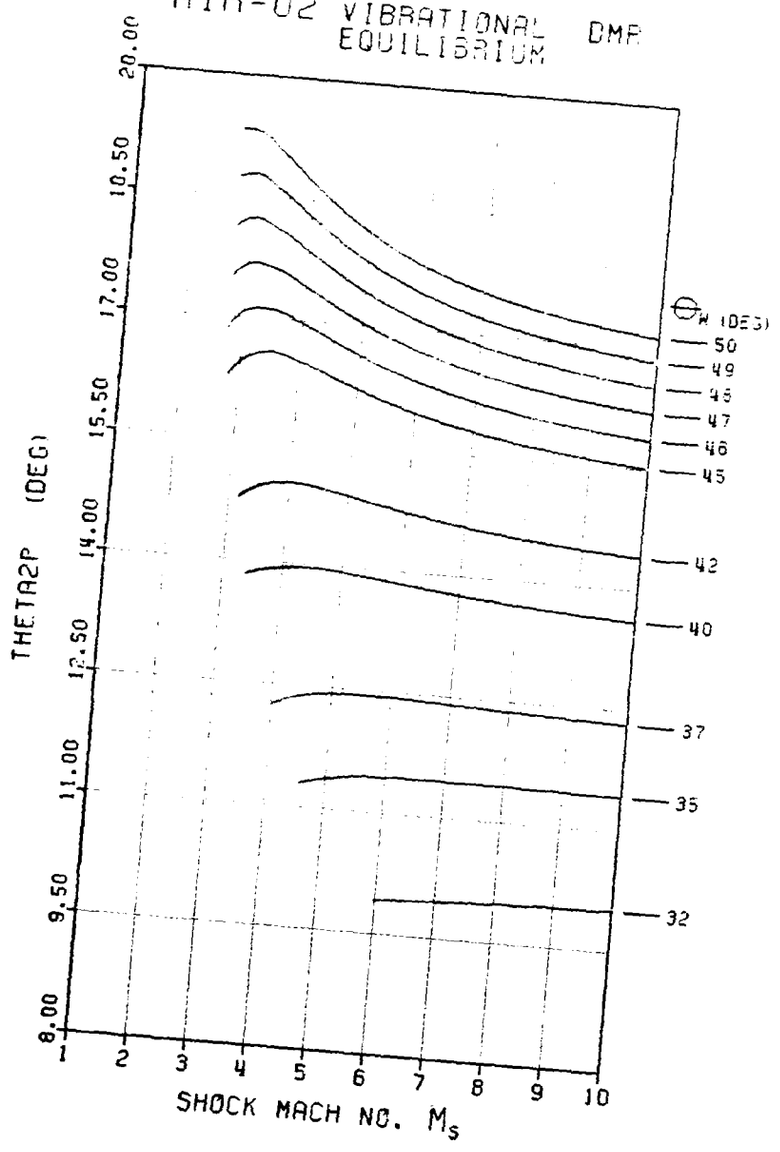
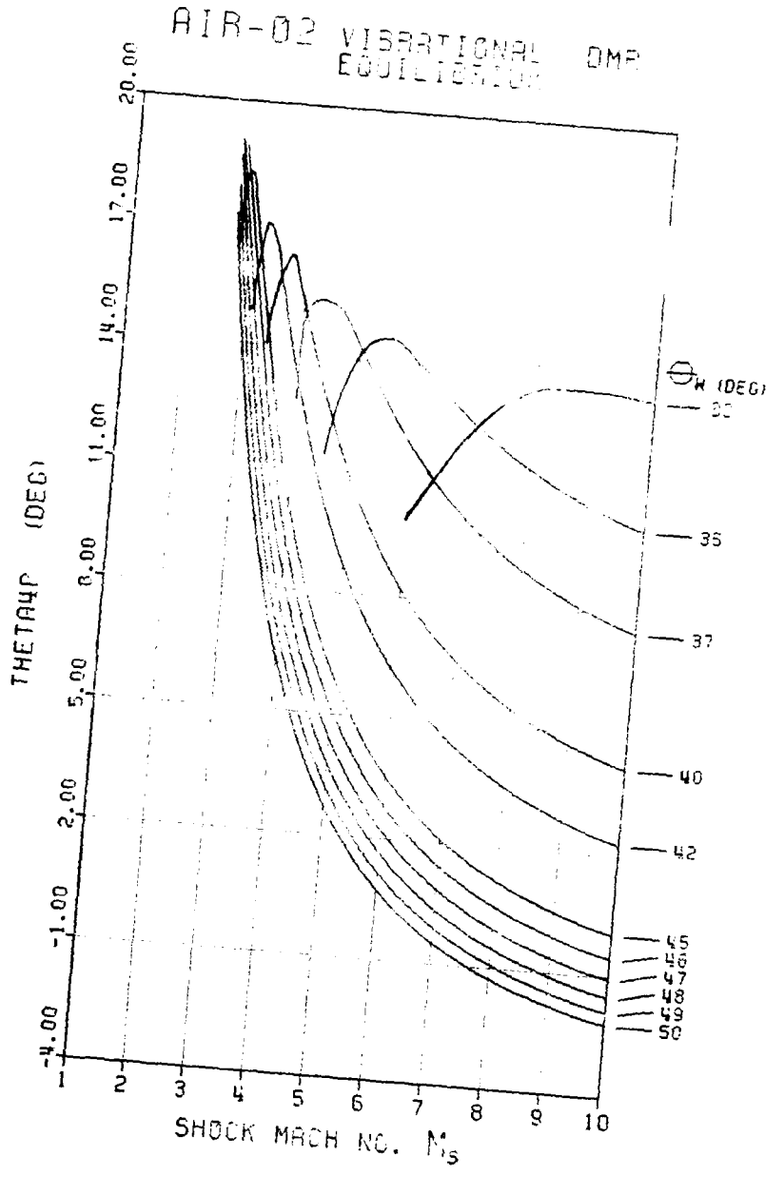
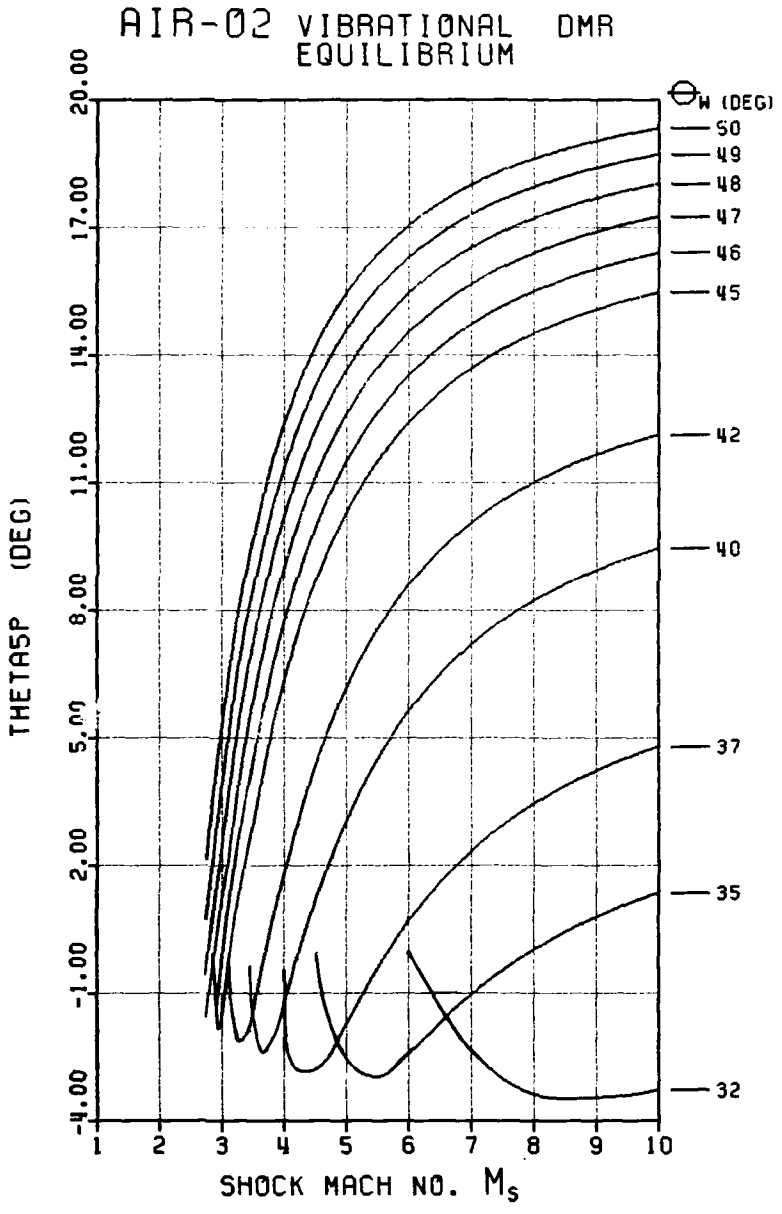
46
47
48
49
50

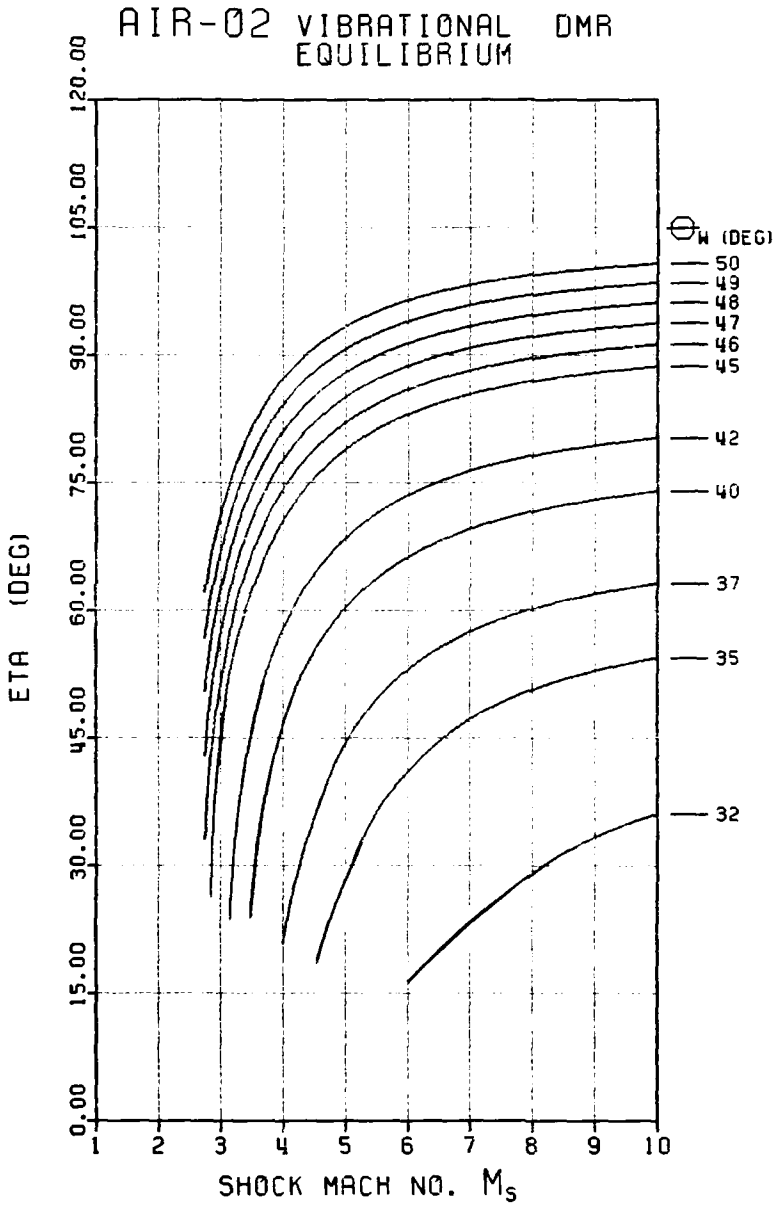

AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
PH12P (DEG)
120.00
112.00
104.00
96.00
88.00
80.00
72.00
64.00
56.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
37
40
42
45
46
47
48
49
50

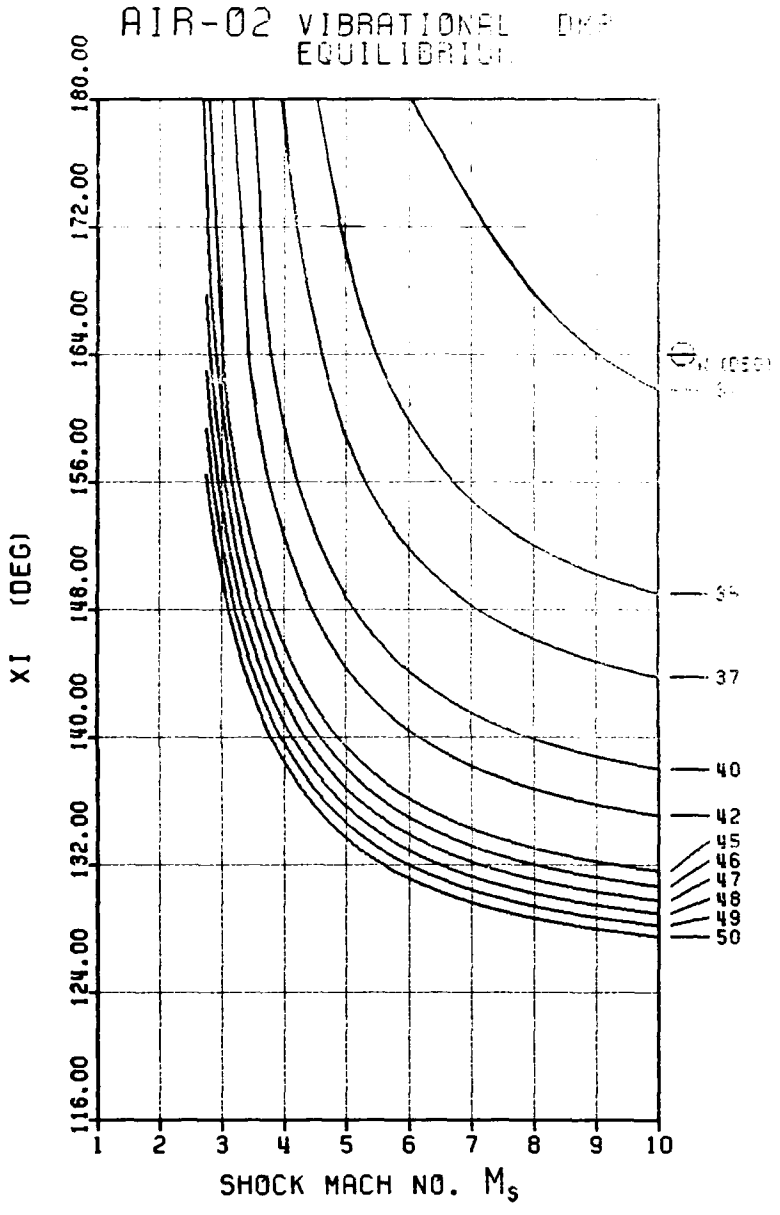

AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
PH14P (DEG)
96.00
91.00
86.00
81.00
76.00
71.00
66.00
61.00
56.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

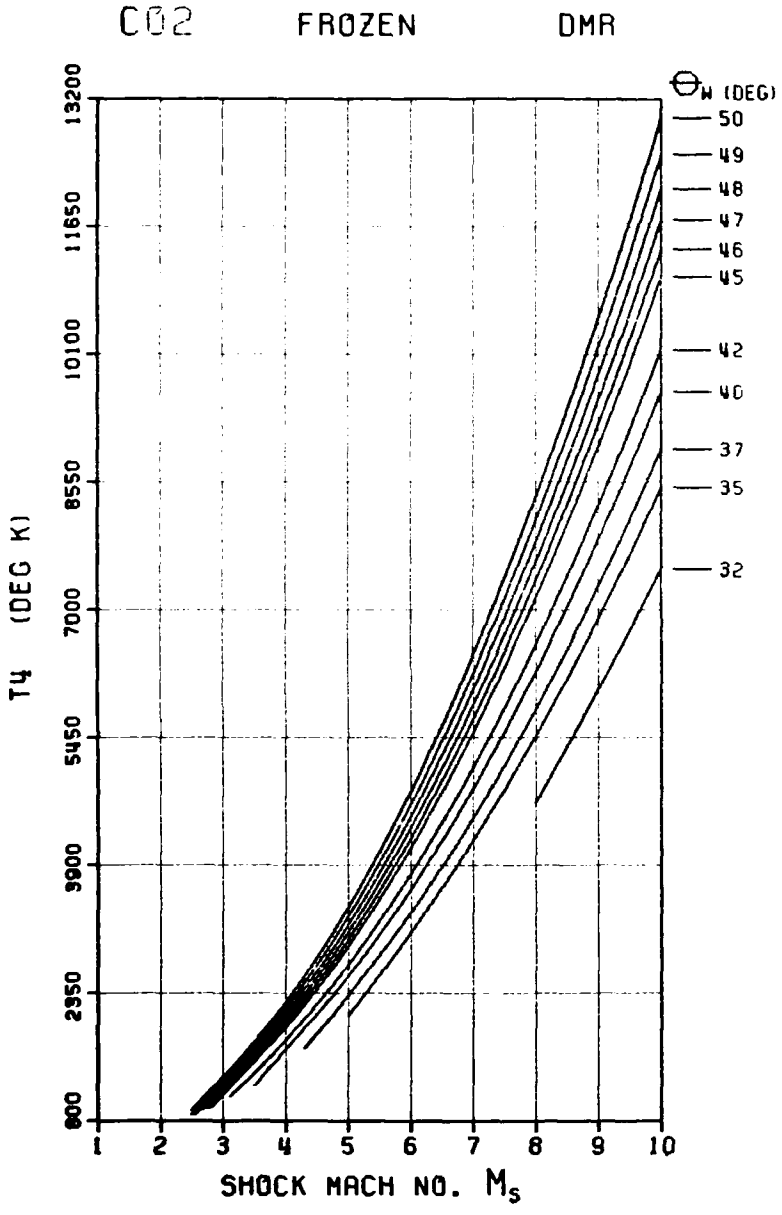

AIR-02 VIBRATIONAL EQUILIBRIUM DMP
THETA2P (DEG)
20.00
10.50
17.00
15.50
14.00
12.50
11.00
9.50
8.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

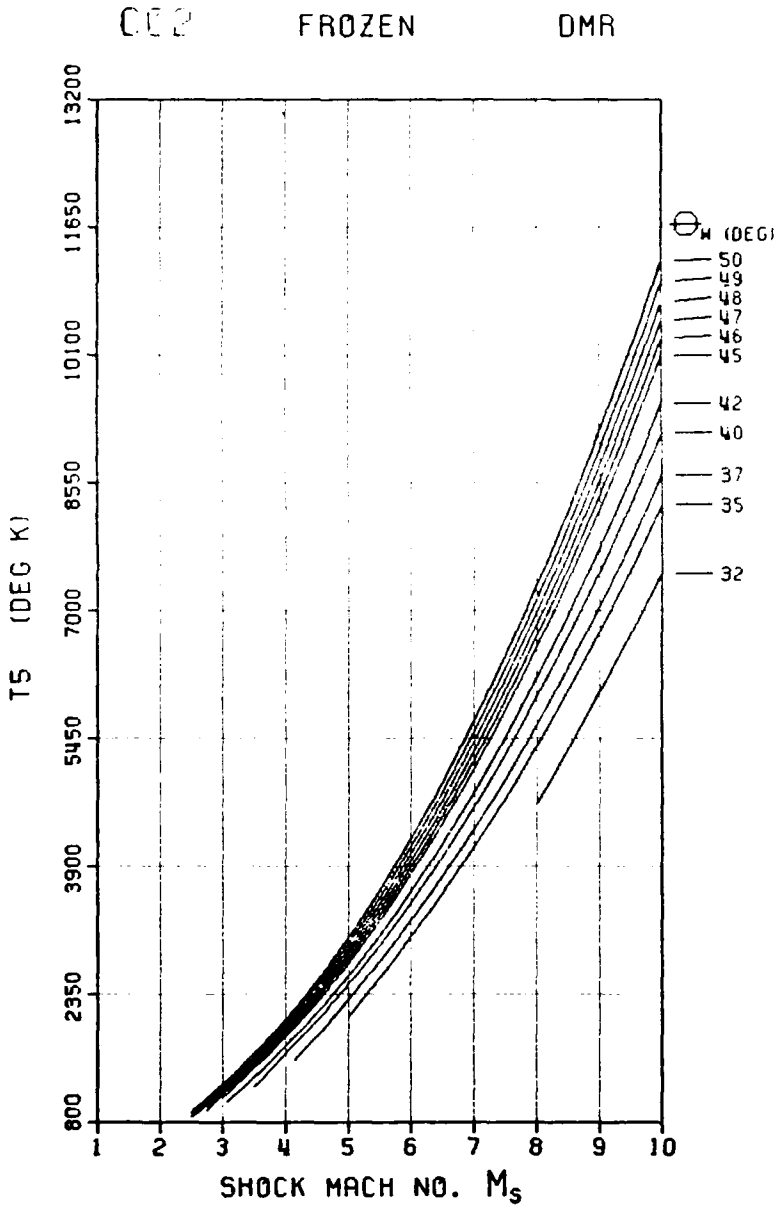

AIR-02 VIBRATIONAL EQUILIBRIUM DMP
THETA4P (DEG)
20.00
17.00
14.00
11.00
8.00
5.00
2.00
-1.00
-4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
35
37
40
42
45
46
47
48
49
50

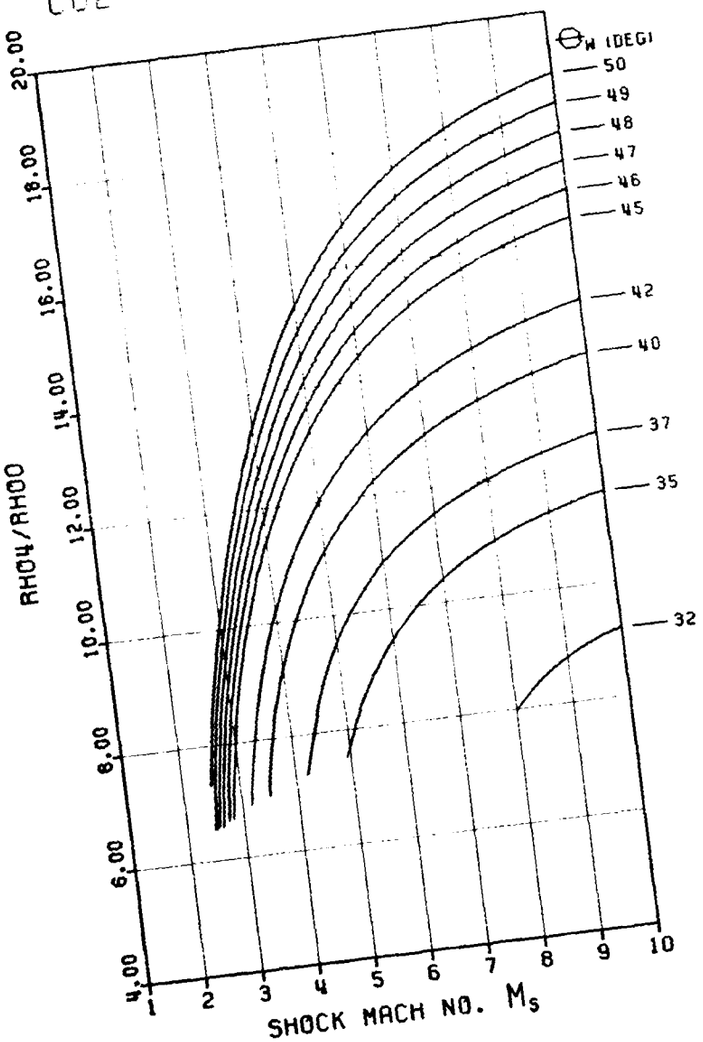

AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
THETA5P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
20.00
17.00
14.00
11.00
8.00
5.00
2.00
-1.00
-4.00
1
2
3
4
5
6
7
8
9
10

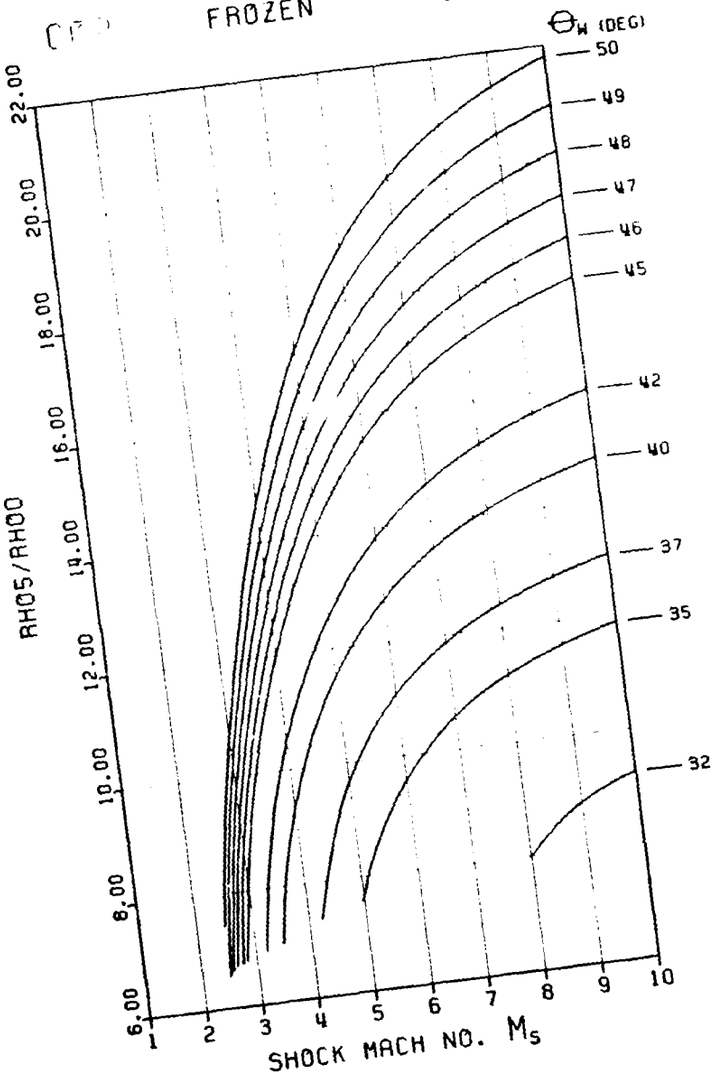

AIR-02 VIBRATIONAL DMR
EQUILIBRIUM
ETA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
1
2
3
4
5
6
7
8
9
10

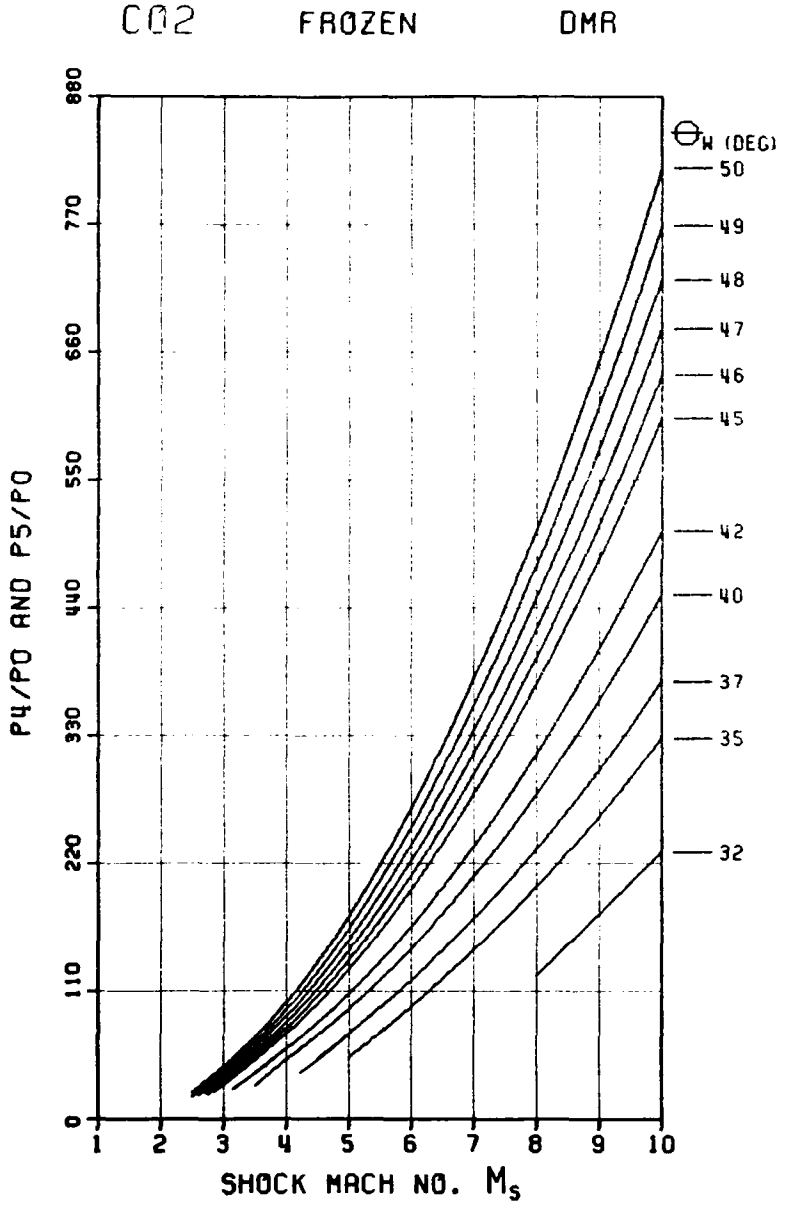

AIR-02 VIBRATIONAL
EQUILIBRIU
XI (DEG)
180.00
172.00
164.00
156.00
148.00
140.00
132.00
124.00
116.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
37
40
42
45
46
47
48
49
50

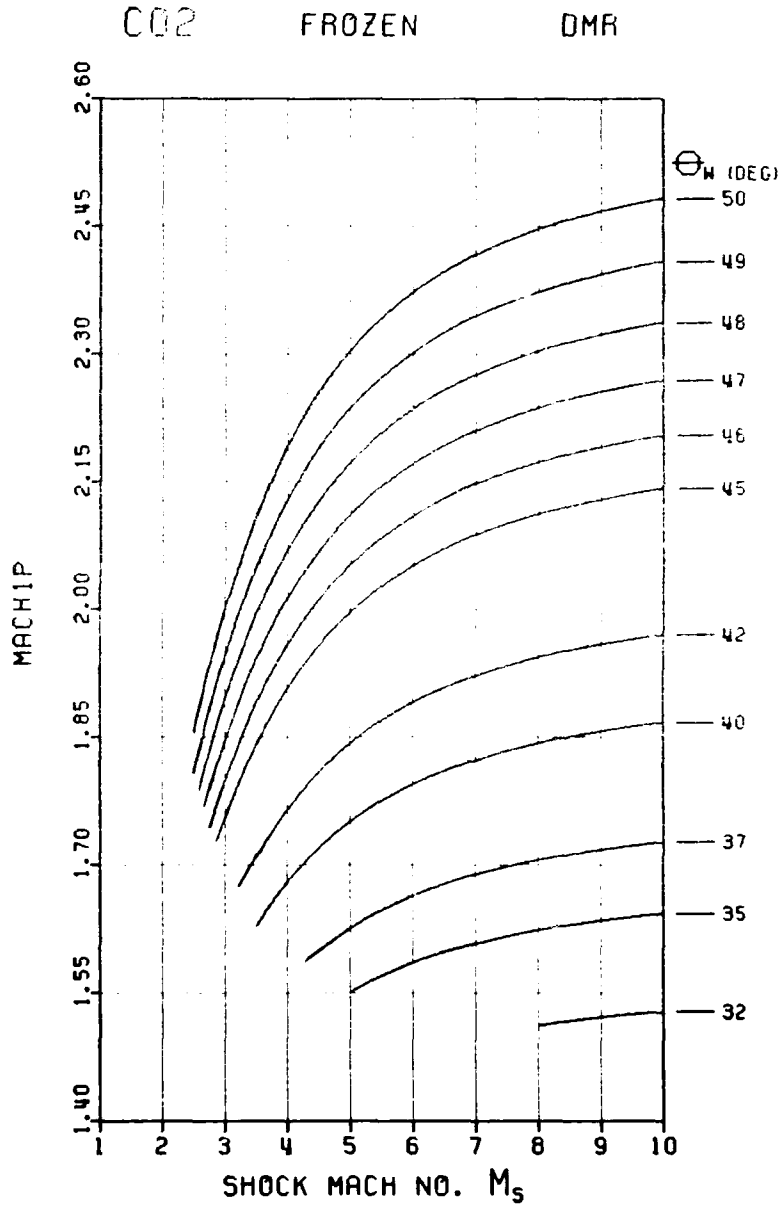

CO2 FROZEN DMR
T4 (DEG K)
800
2350
3900
5450
7000
8550
10100
11650
13200
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32


CO2 FROZEN DMR
T5 (DEG K)
800
2350
3900
5450
7000
8550
10100
11650
13200
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32


FROZEN
DMR
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
RHO4/RHO0
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S


FROZEN
DMR
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
RHO5/RHO0
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S


CO2 FROZEN DMR
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
0
110
220
330
440
550
660
770
880
1
2
3
4
5
6
7
8
9
10


CO2 FROZEN DMR
MACH1P
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
1.40
1.55
1.70
1.85
2.00
2.15
2.30
2.45
2.60
1
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3
4
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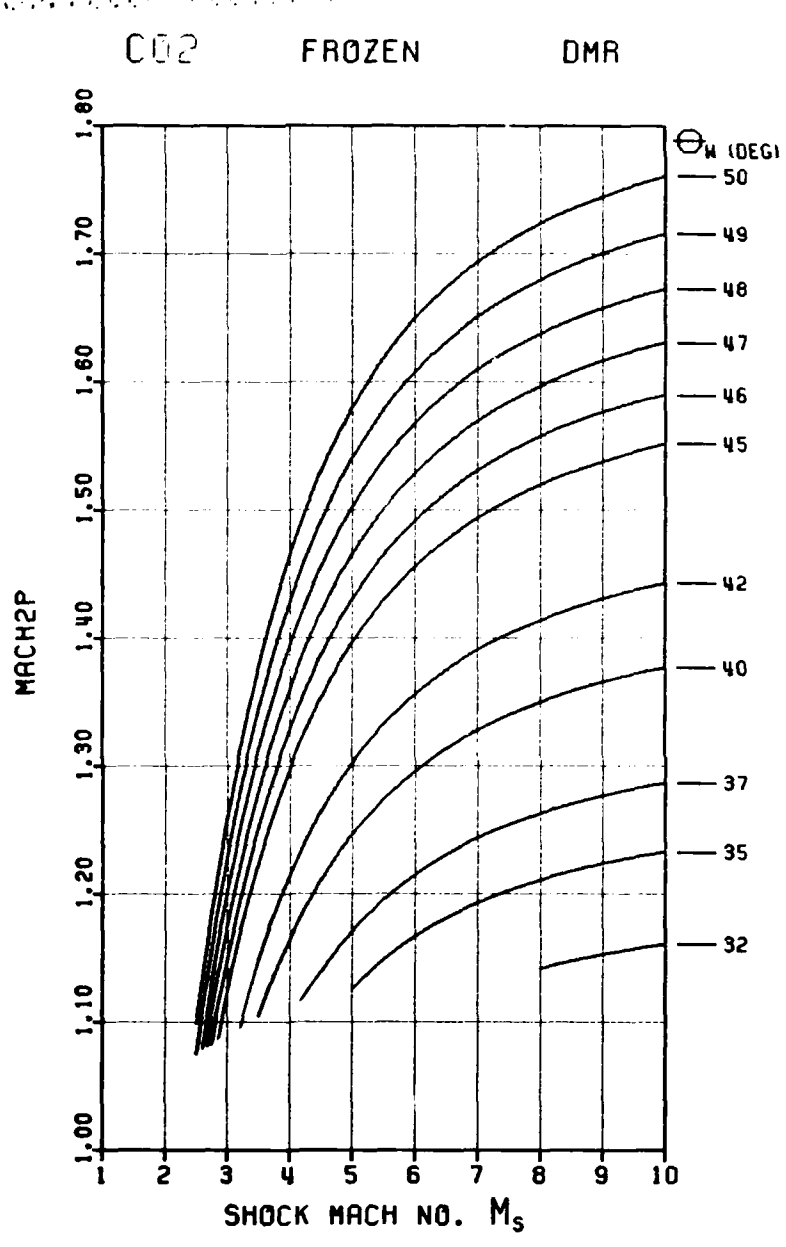
6
7
8
9
10


CO2 FROZEN DMR
MACH2P
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
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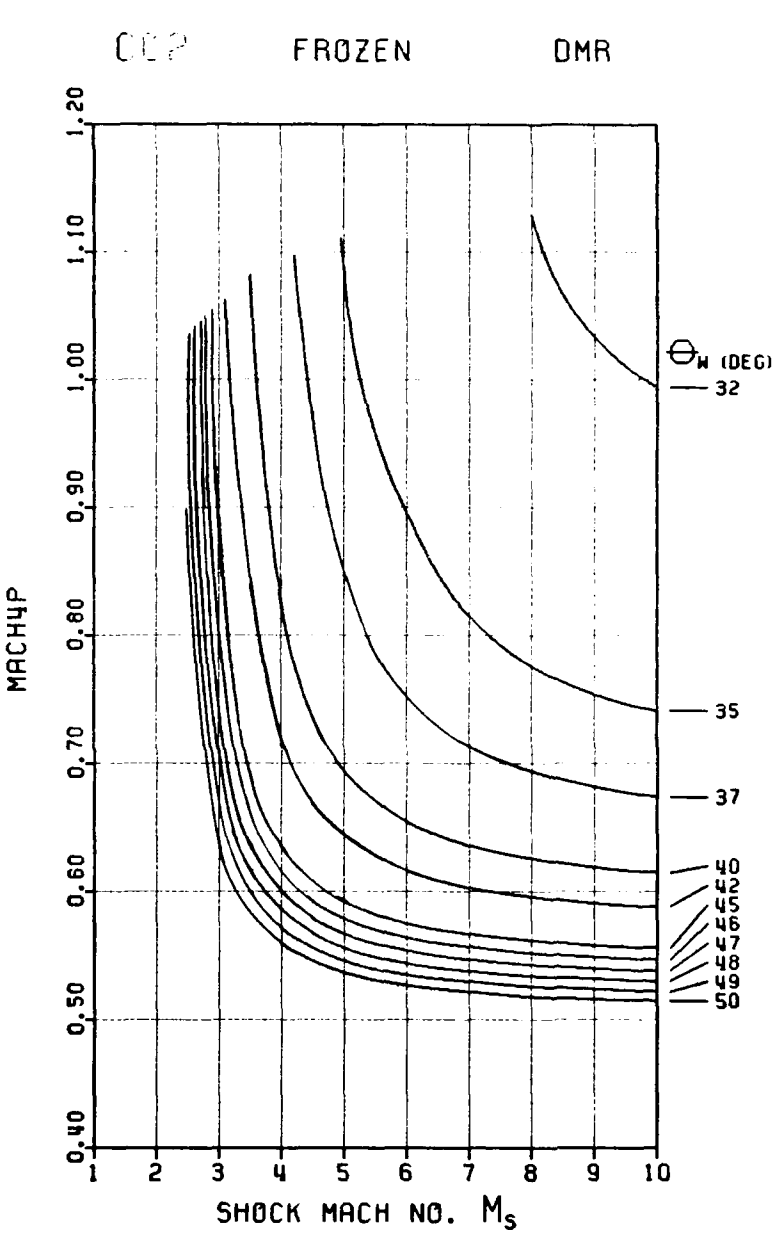
47
46
45
42
40
37
35
32


CO2 FROZEN DMR
MACH4P
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
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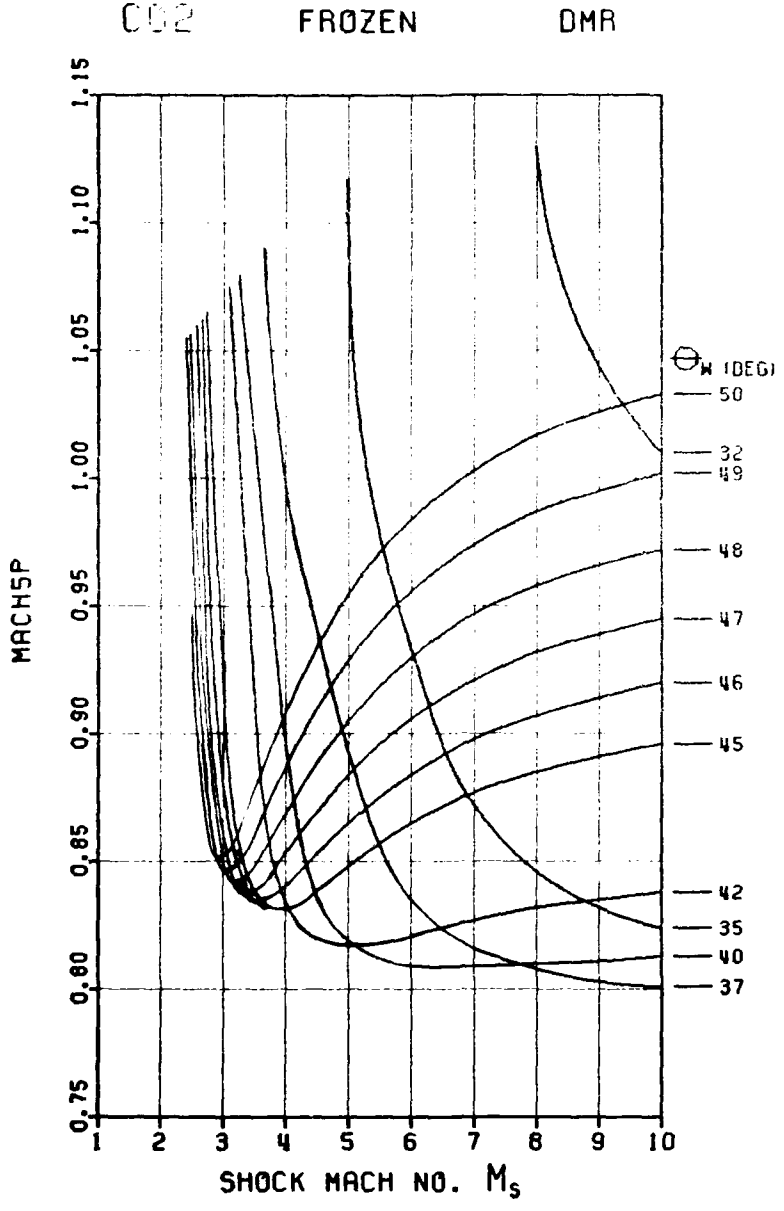
40
42
45
46
47
48
49
50


CO2 FROZEN DMR
MACHSP
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32
0.75
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1
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3
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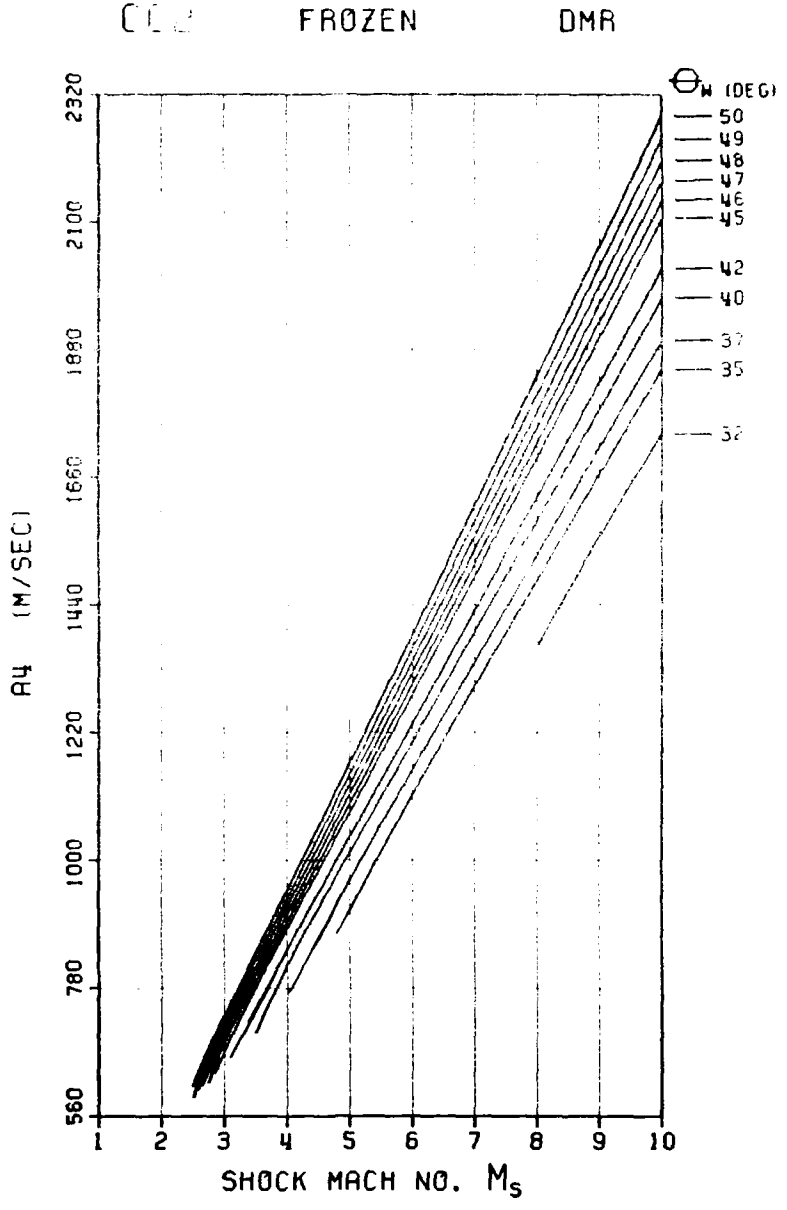
9
10


CO2 FROZEN DMR
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
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49
48
47
46
45
42
40
37
35
32
560
780
1000
1220
1440
1660
1880
2100
2320
1
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3
4
5
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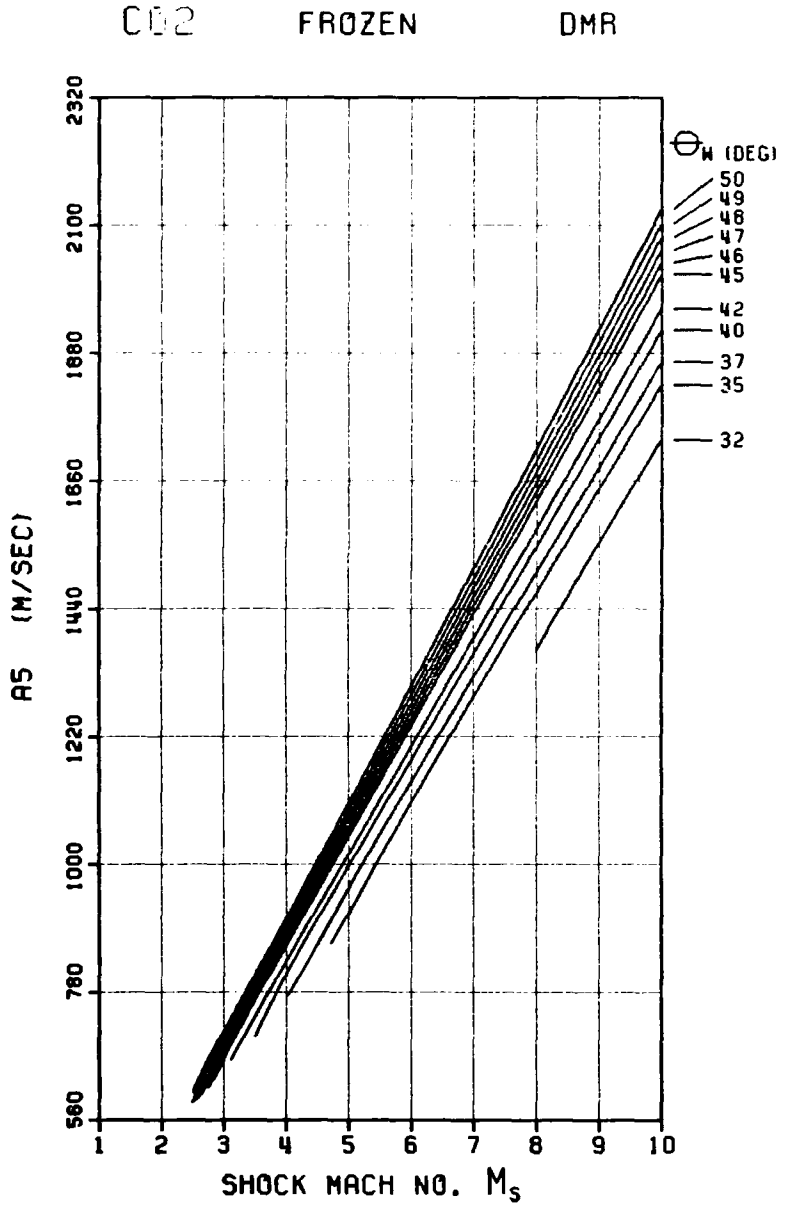
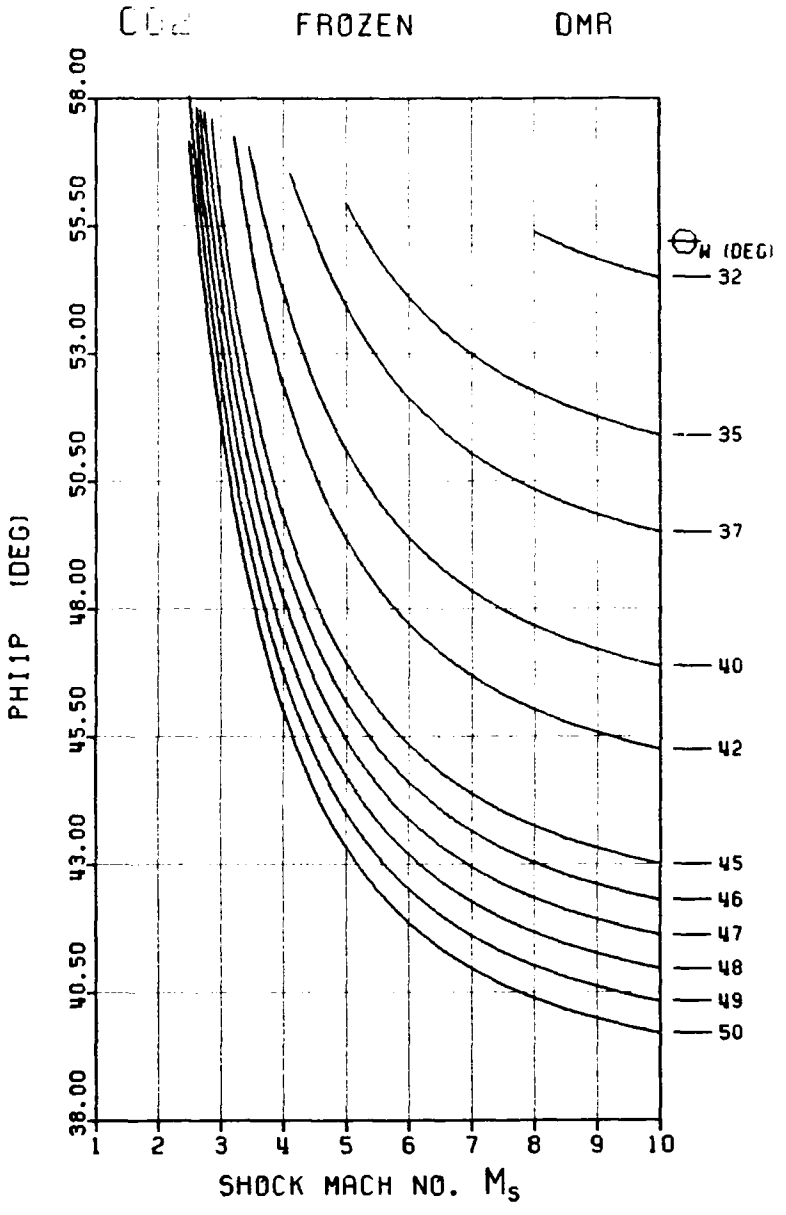
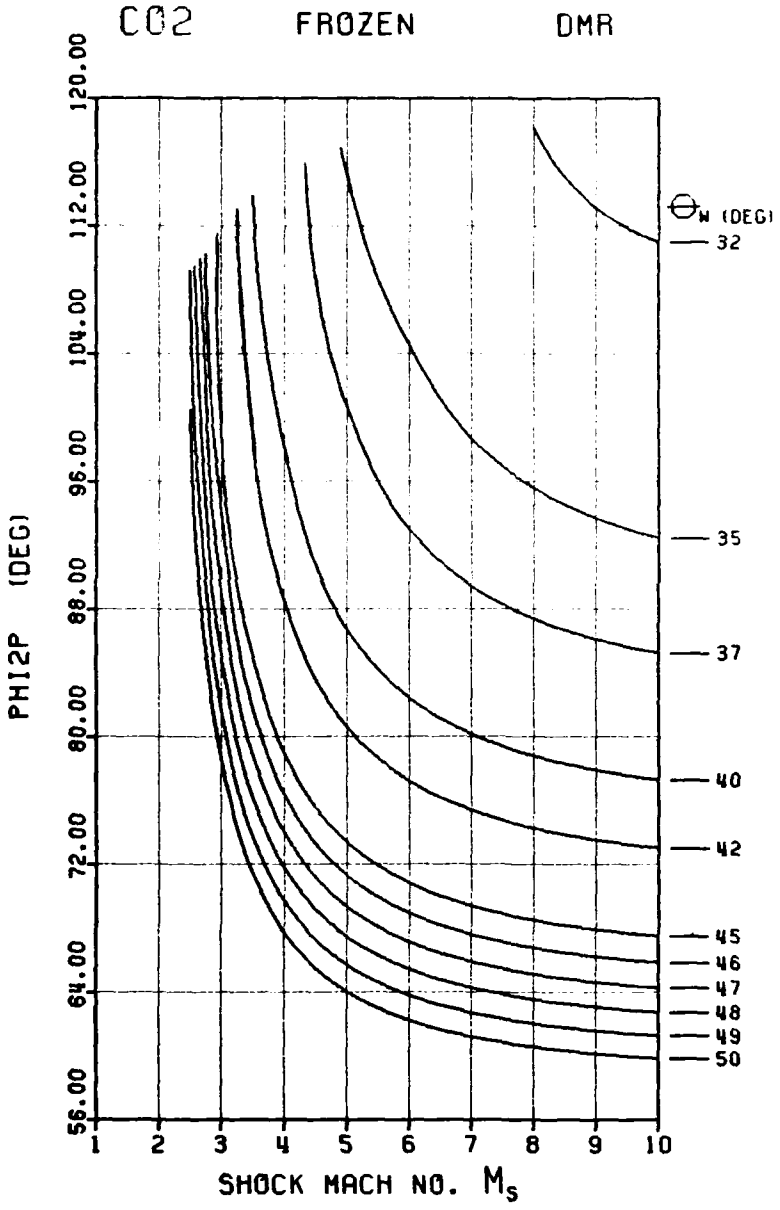
7
8
9
10


CO2 FROZEN DMR
A5 (M/SEC)
2320
2100
1880
1660
1440
1220
1000
780
560
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32


CO2 FROZEN DMR
PHI1P (DEG)
58.00
55.50
53.00
50.50
48.00
45.50
43.00
40.50
38.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
37
40
42
45
46
47
48
49
50


C02 FROZEN DMR
PHI2P (DEG)
SHOCK MACH NO. M_s
θ_w (DEG)
32
35
37
40
42
45
46
47
48
49
50
120.00
112.00
104.00
96.00
88.00
80.00
72.00
64.00
56.00
1
2
3
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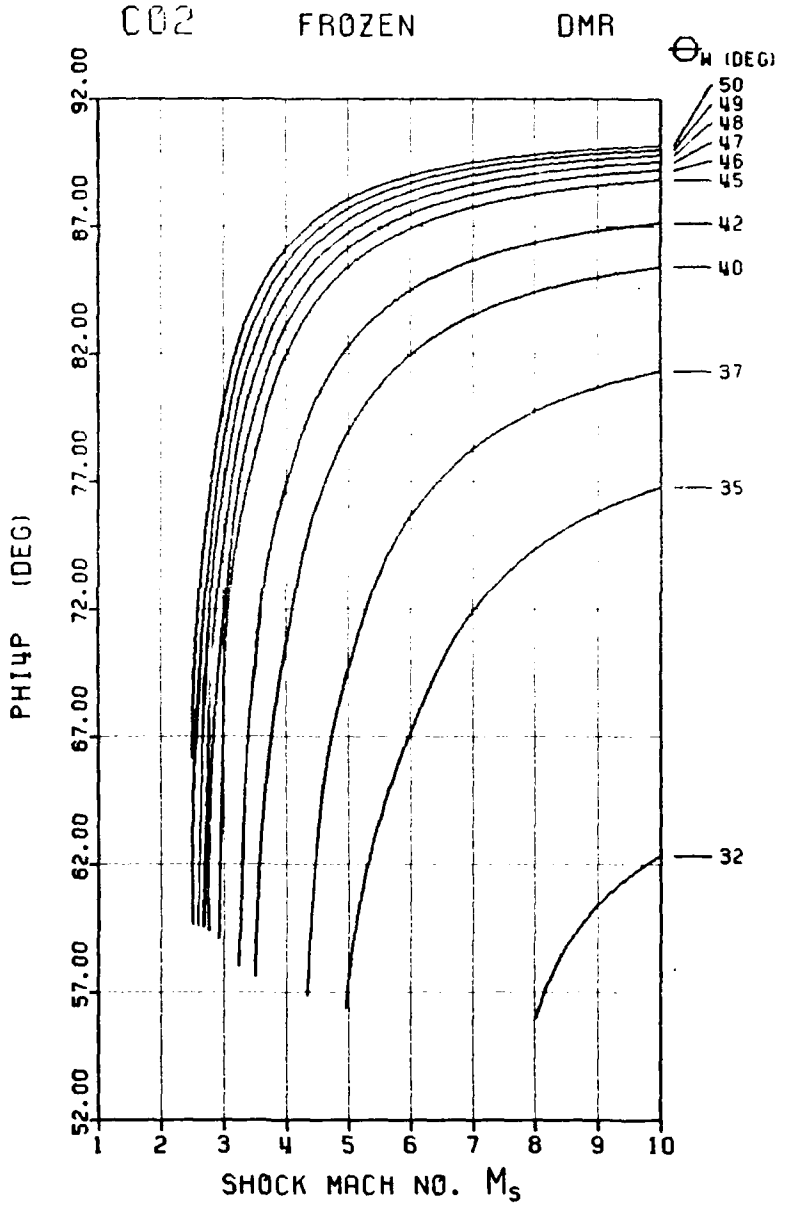
6
7
8
9
10


C02 FROZEN DMR
PHI4P (DEG)
SHOCK MACH NO. M_s
θ_w (DEG)
50
49
48
47
46
45
42
40
37
35
32
92.00
87.00
82.00
77.00
72.00
67.00
62.00
57.00
52.00
1
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3
4
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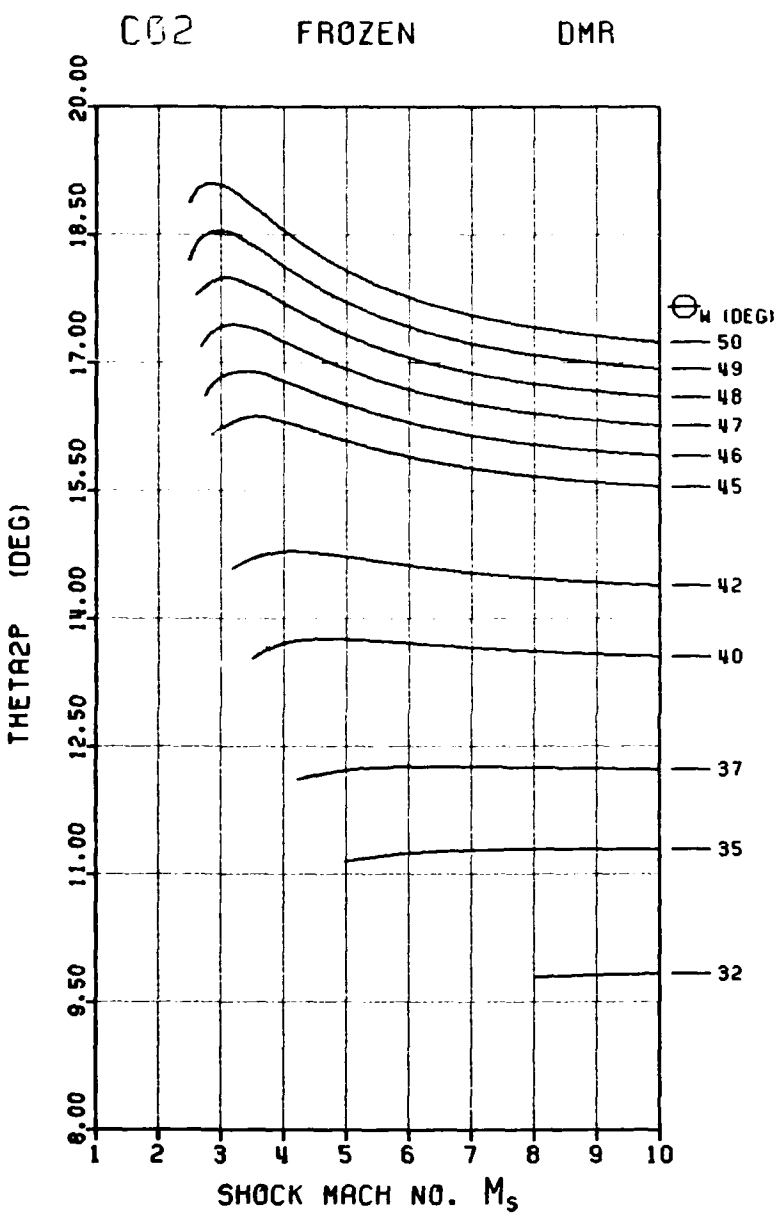
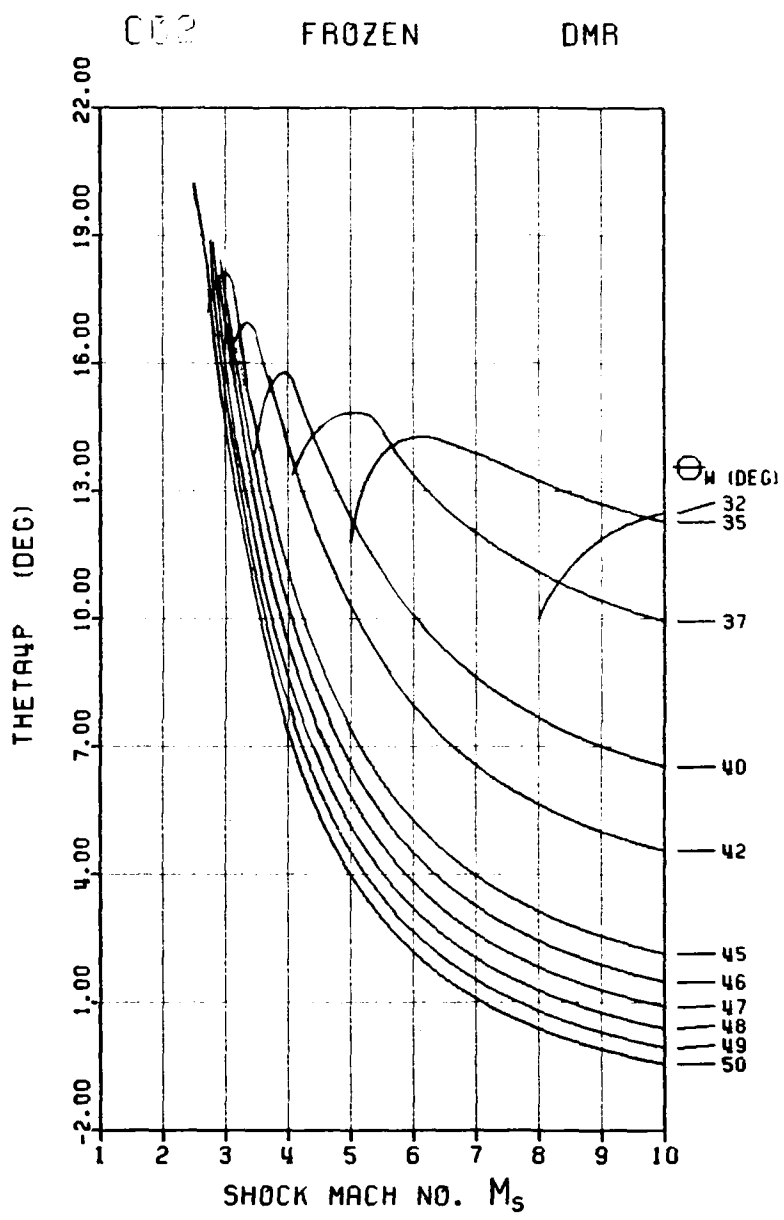
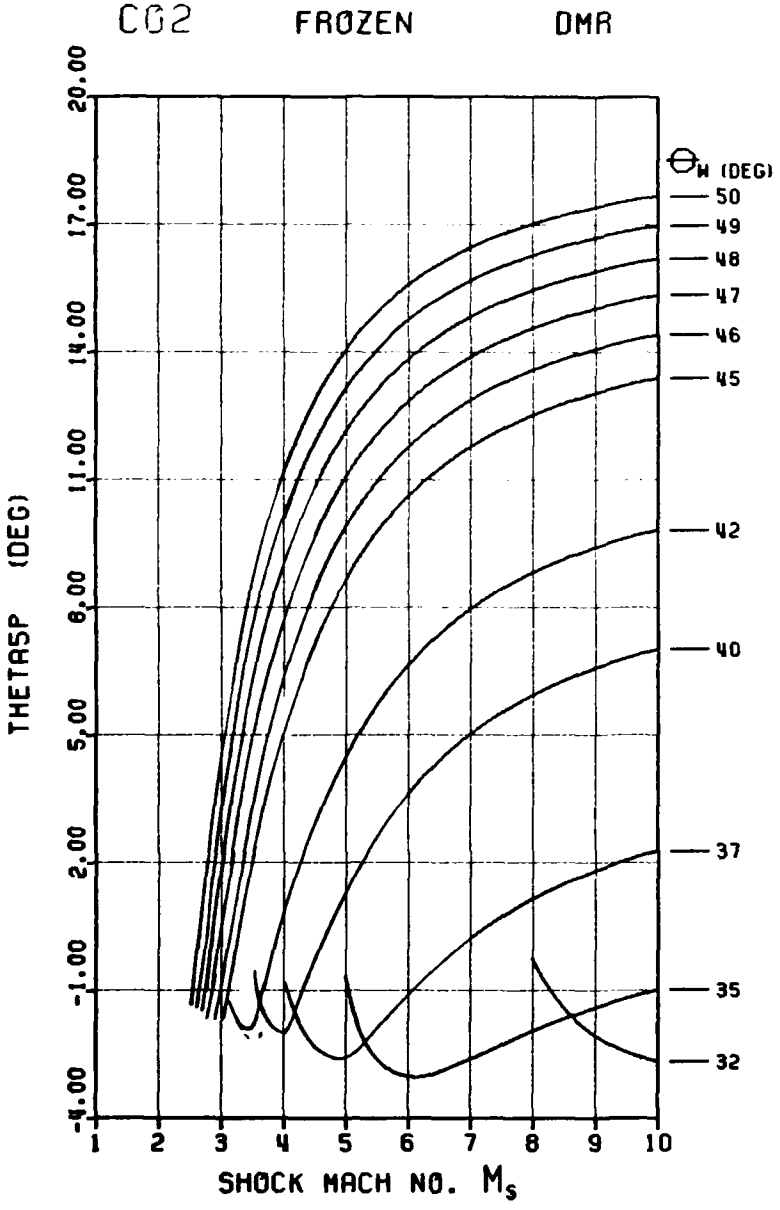
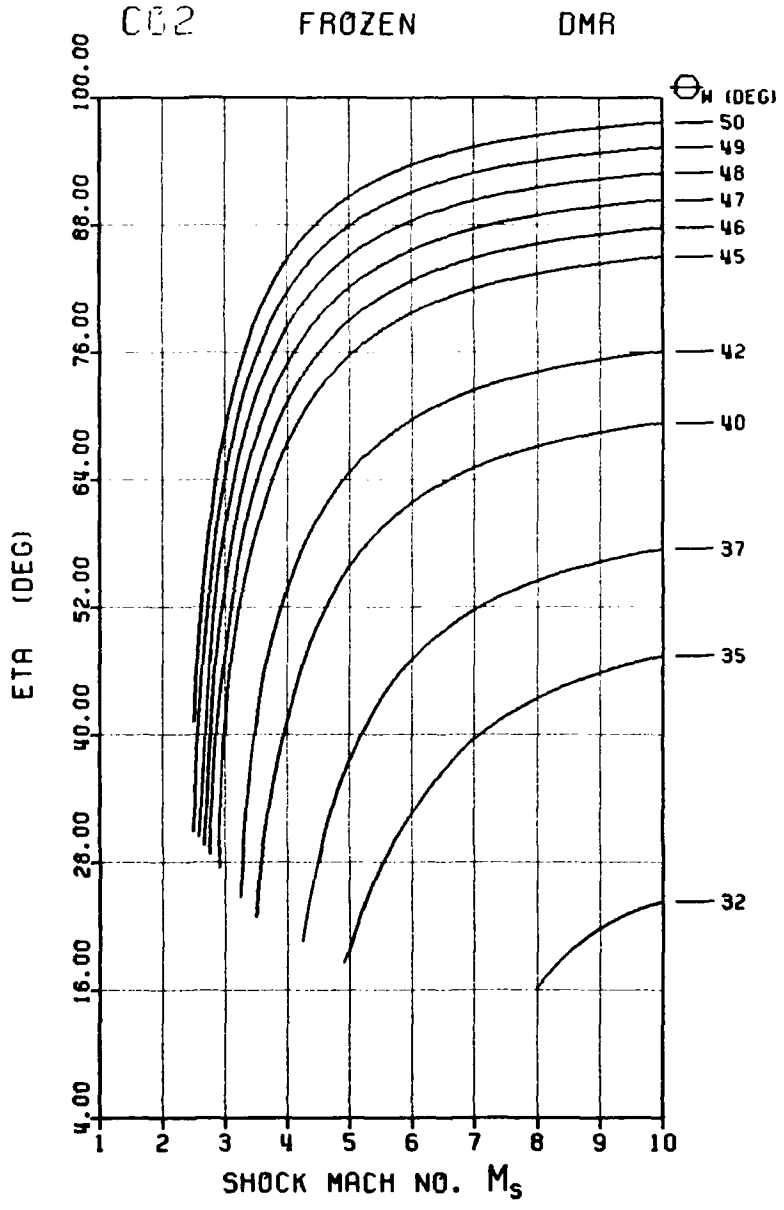
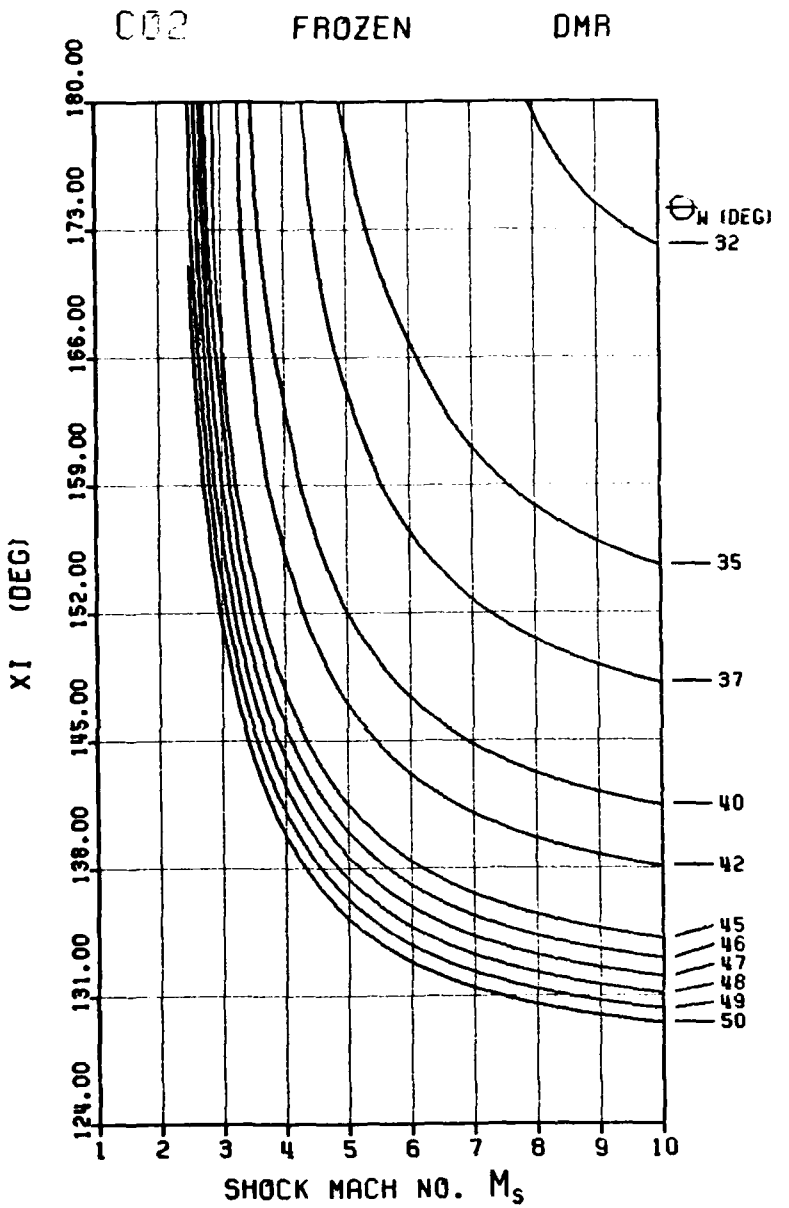
8
9
10

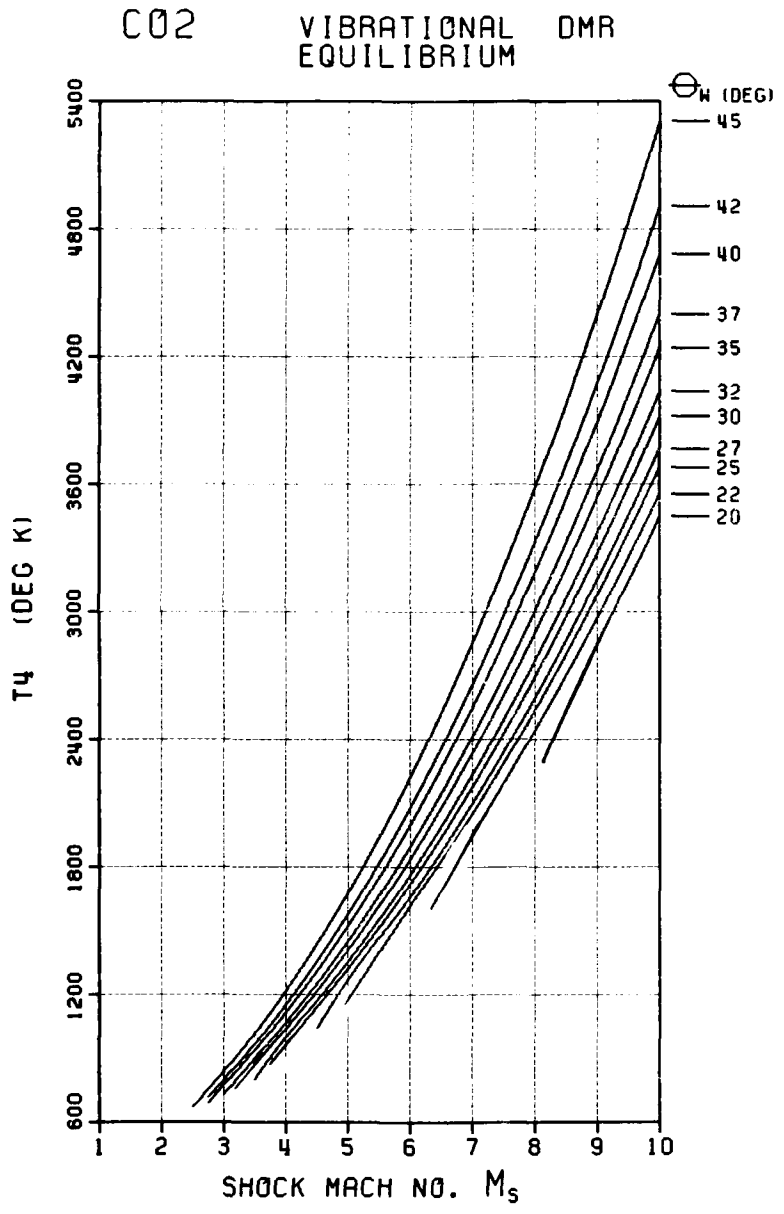

CO2 FROZEN DMR
THETA2P (DEG)
20.00
18.50
17.00
15.50
14.00
12.50
11.00
9.50
8.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

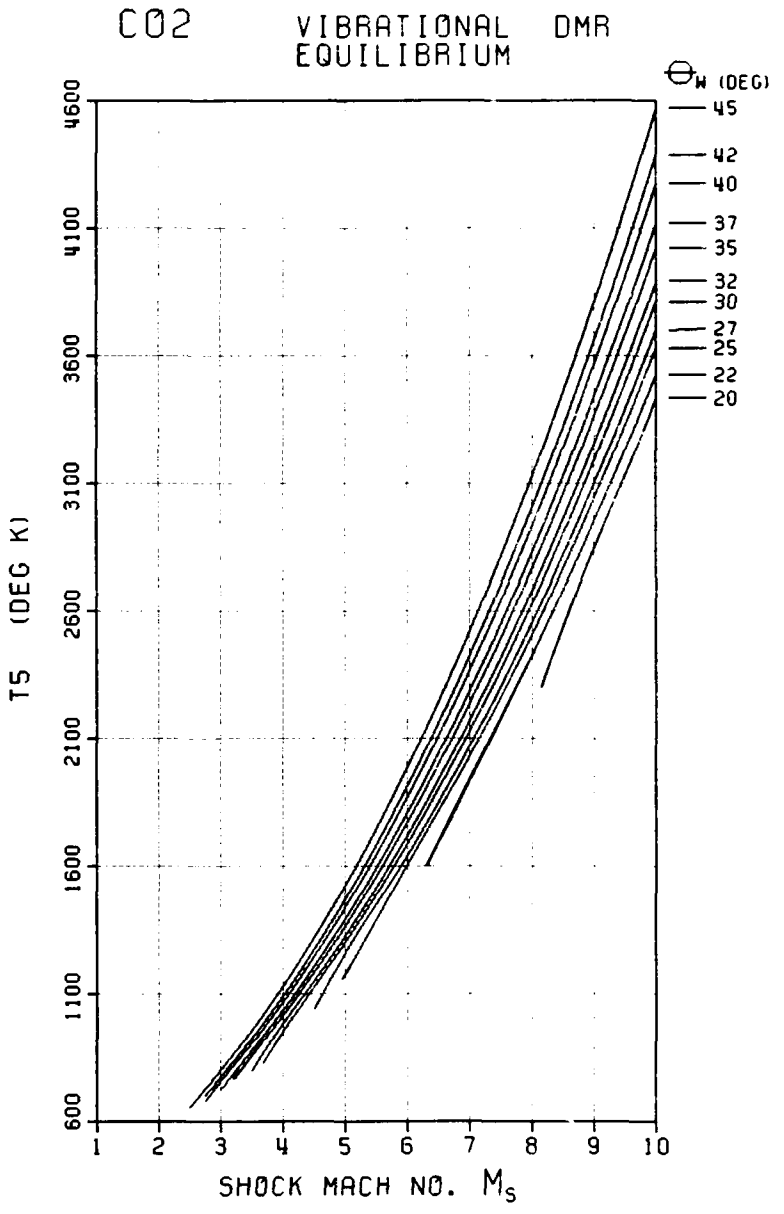

CO2 FROZEN DMR
THETA4P (DEG)
22.00
19.00
16.00
13.00
10.00
7.00
4.00
1.00
-2.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
32
35
37
40
42
45
46
47
48
49
50

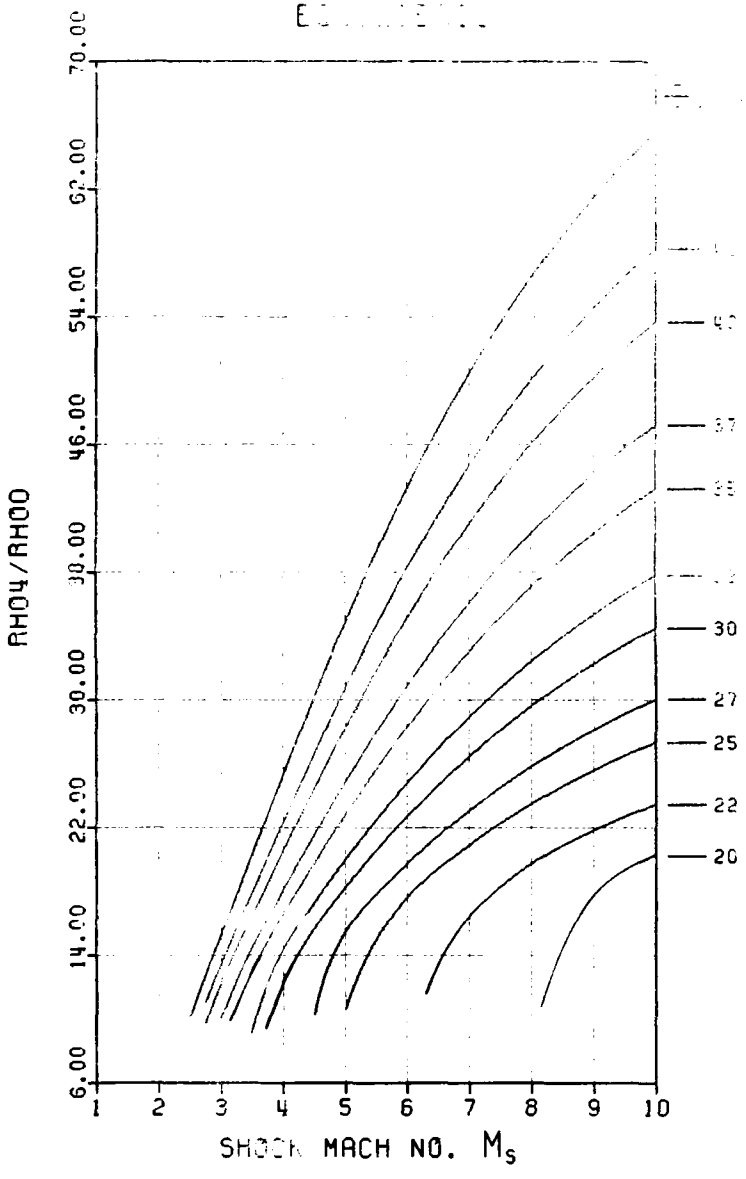

CO2 FROZEN DMR
THETASP (DEG)
20.00
17.00
14.00
11.00
8.00
5.00
2.00
-1.00
-4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

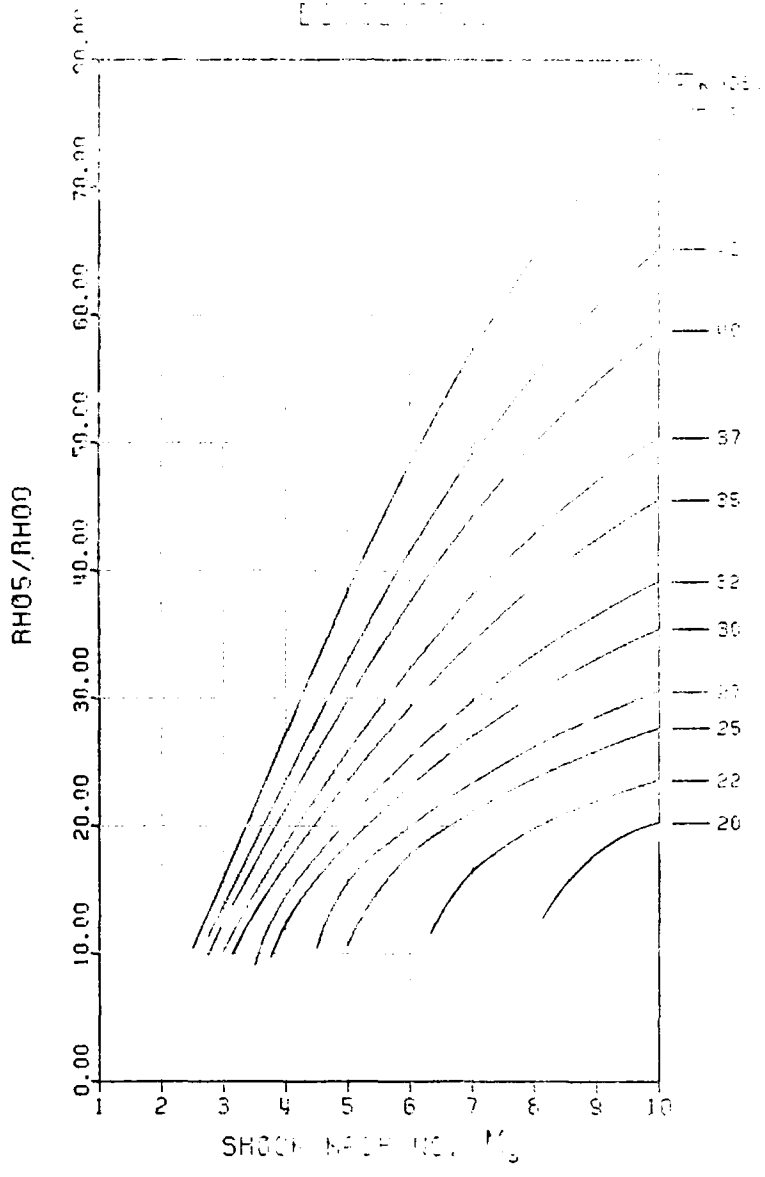

CO2 FROZEN DMR
ETA (DEG)
100.00
88.00
76.00
64.00
52.00
40.00
28.00
16.00
4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
50
49
48
47
46
45
42
40
37
35
32

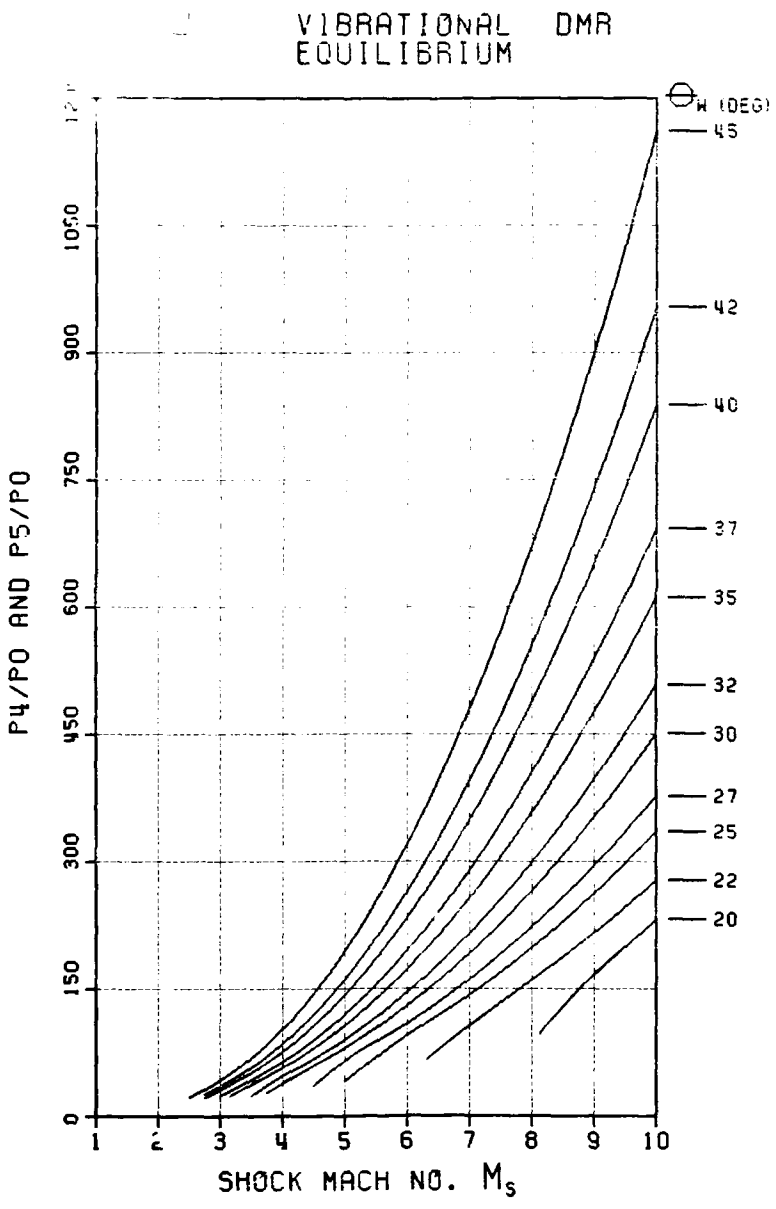

CO2 FROZEN DMR
XI (DEG)
180.00
173.00
166.00
159.00
152.00
145.00
138.00
131.00
124.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_N (DEG)
32
35
37
40
42
45
46
47
48
49
50

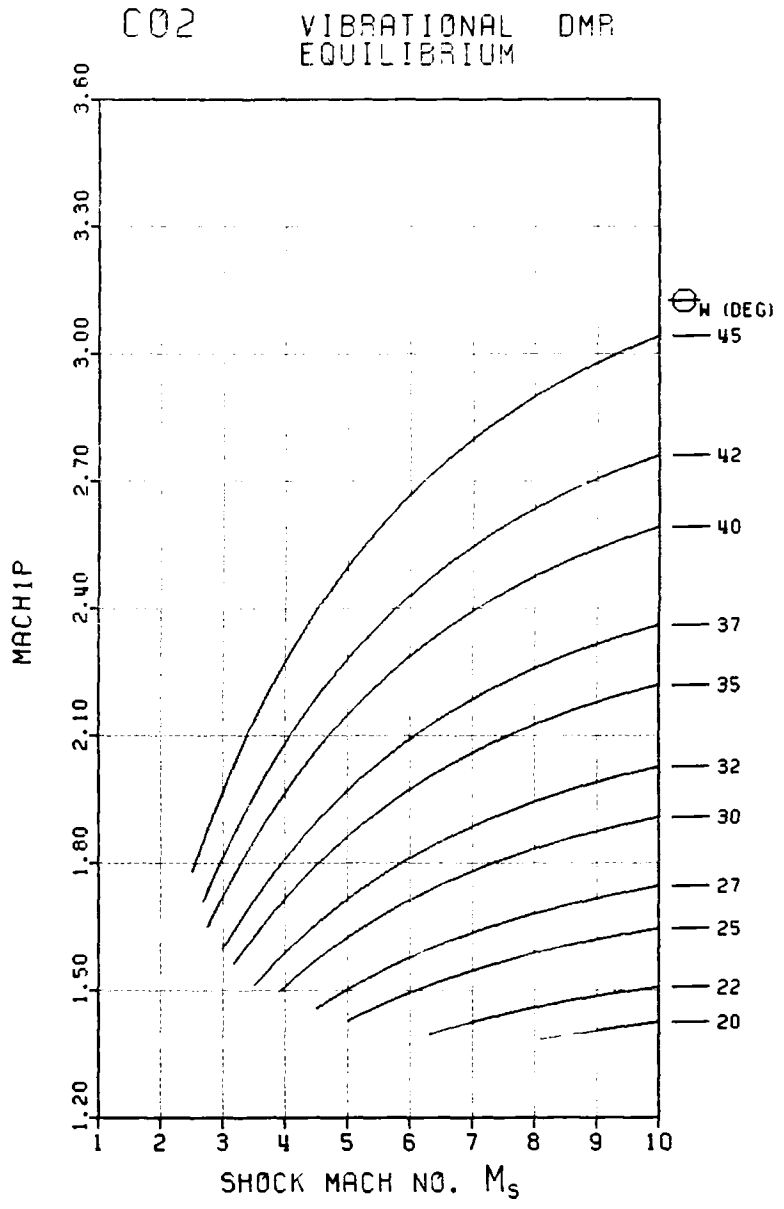

C02 VIBRATIONAL DMR EQUILIBRIUM
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
T4 (DEG K)
600
1200
1800
2400
3000
3600
4200
4800
5400
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

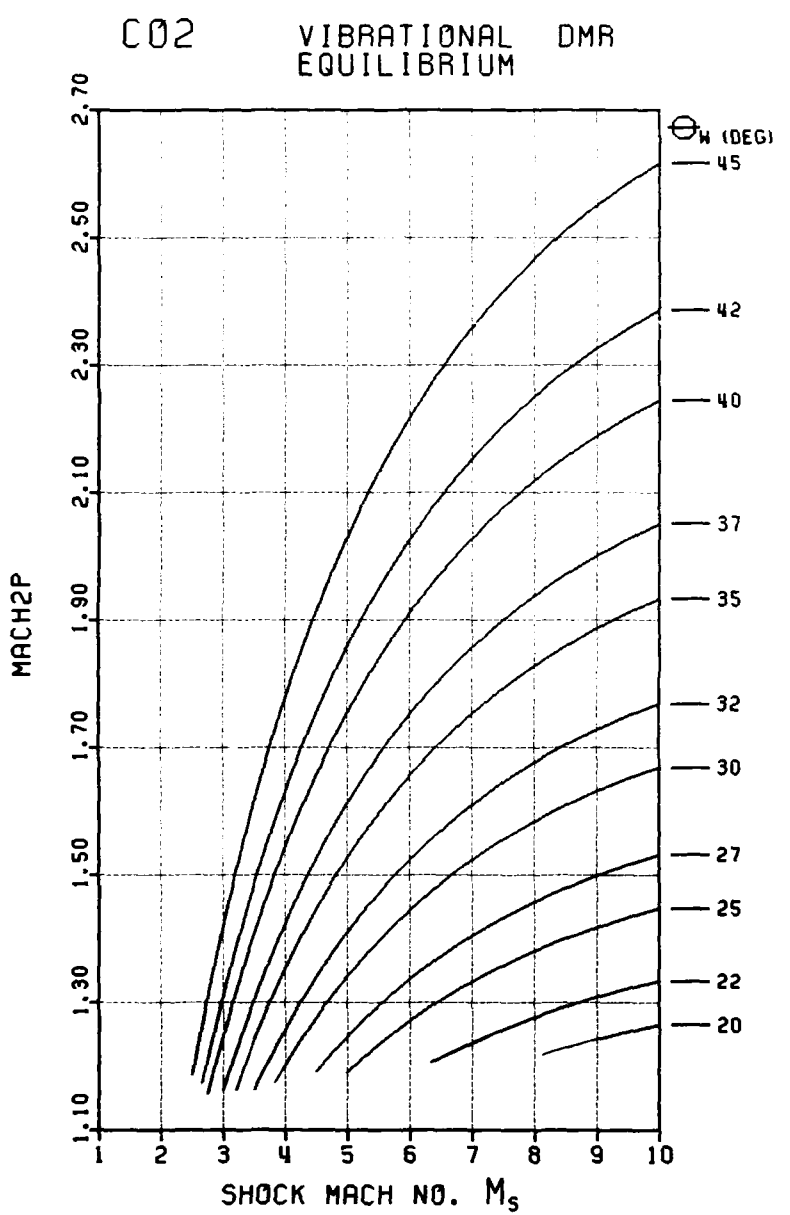

C02 VIBRATIONAL DMR EQUILIBRIUM
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
T5 (DEG K)
600
1100
1600
2100
2600
3100
3600
4100
4600
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S

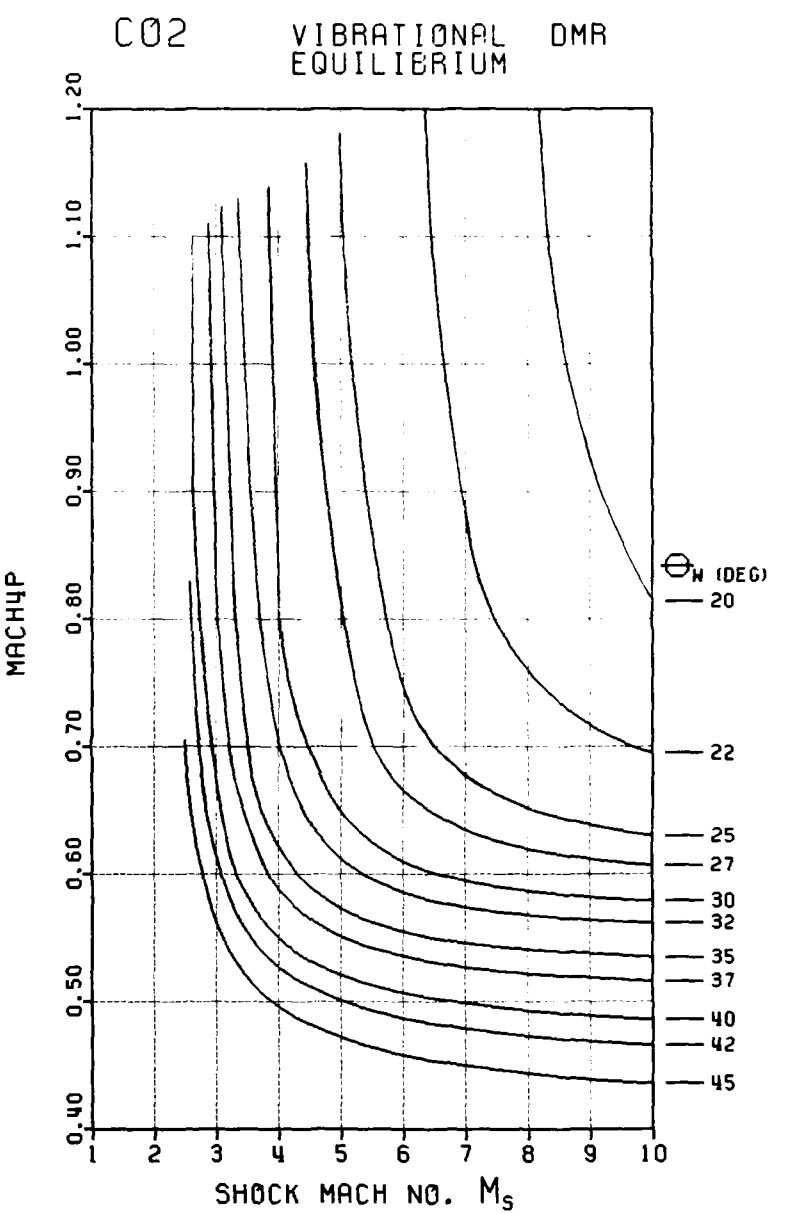

RH04/RH00
70.00
62.00
54.00
46.00
38.00
30.00
22.00
14.00
6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
30
27
25
22
20

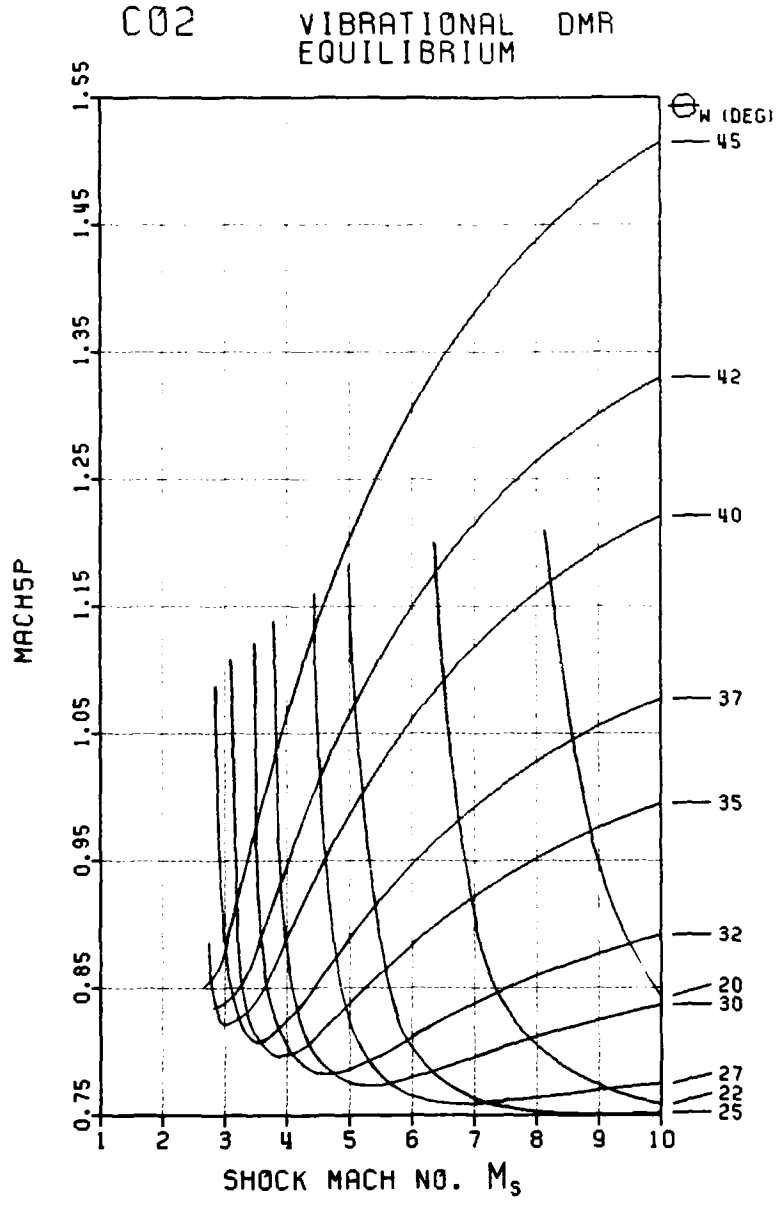

RH05/RH00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1 2 3 4 5 6 7 8 9 10
37
35
32
30
25
22
20

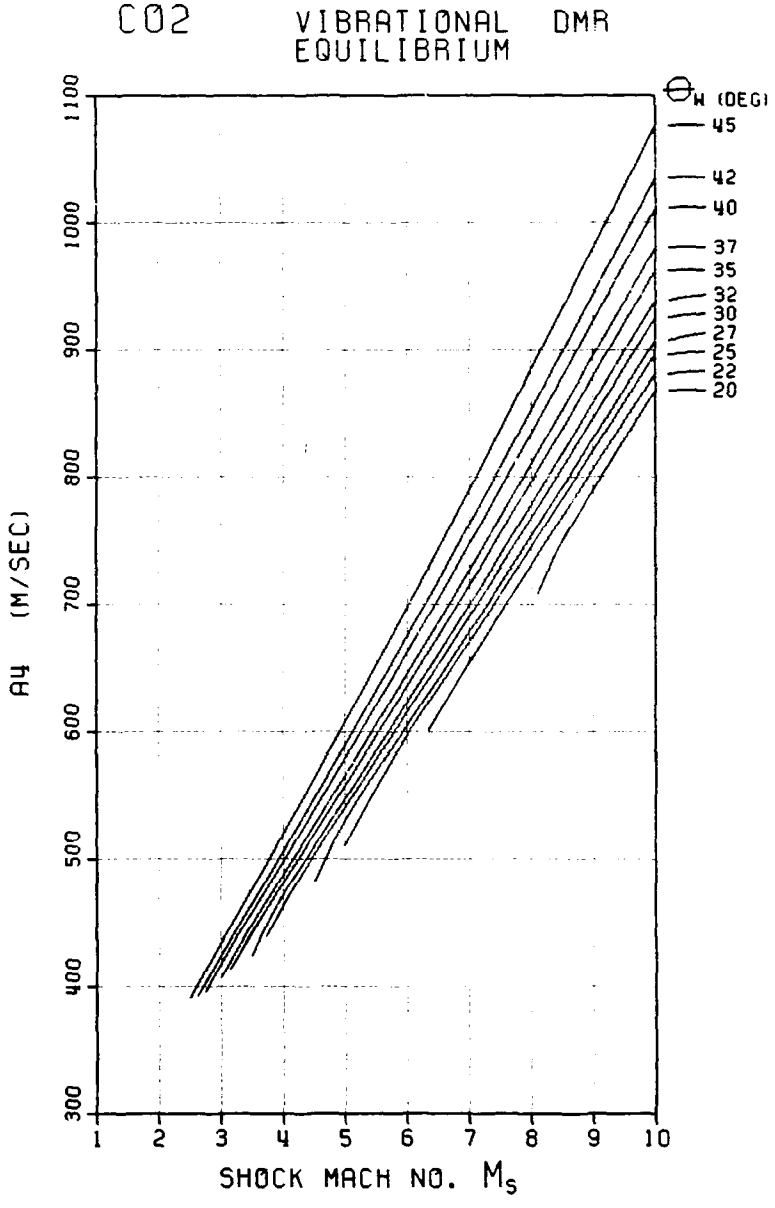

VIBRATIONAL DMR
EQUILIBRIUM
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
0
150
300
450
600
750
900
1050
1
2
3
4
5
6
7
8
9
10

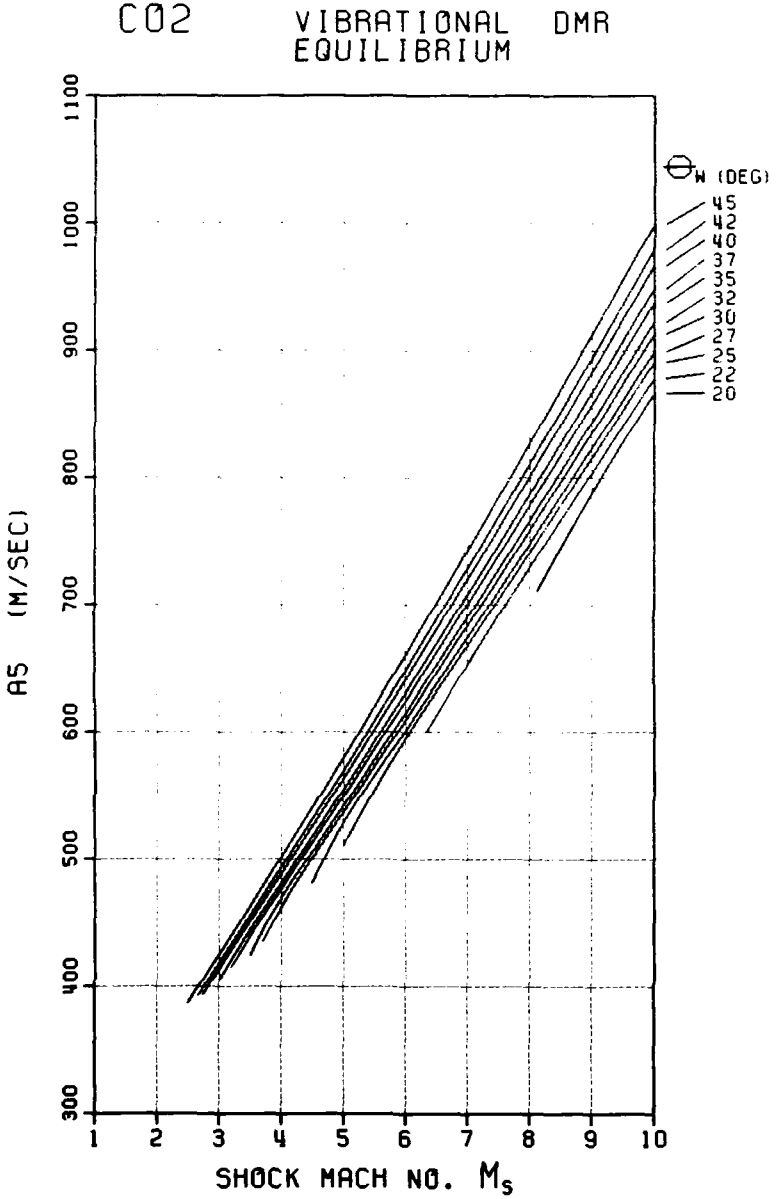

CO2
VIBRATIONAL DMR
EQUILIBRIUM
MACH1P
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
1.20
1.50
1.80
2.10
2.40
2.70
3.00
3.30
3.60
1
2
3
4
5
6
7
8
9
10

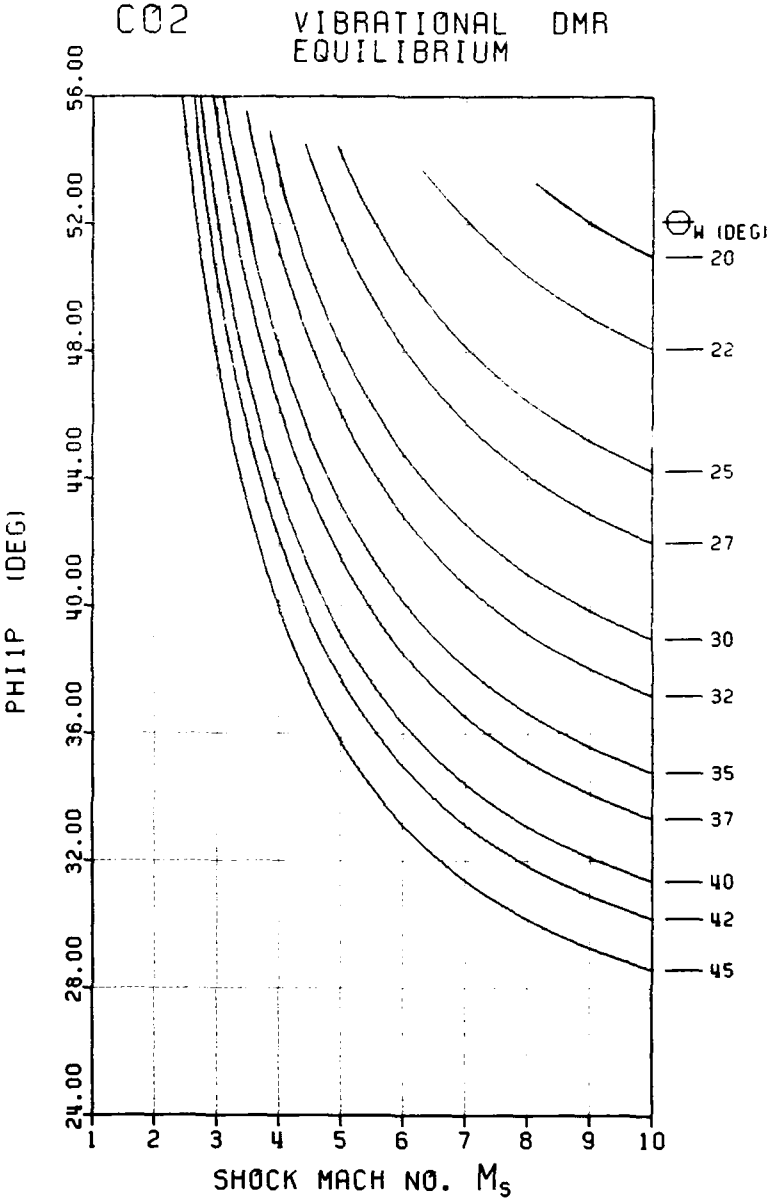

C02 VIBRATIONAL DMR
EQUILIBRIUM
MACH2P
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20

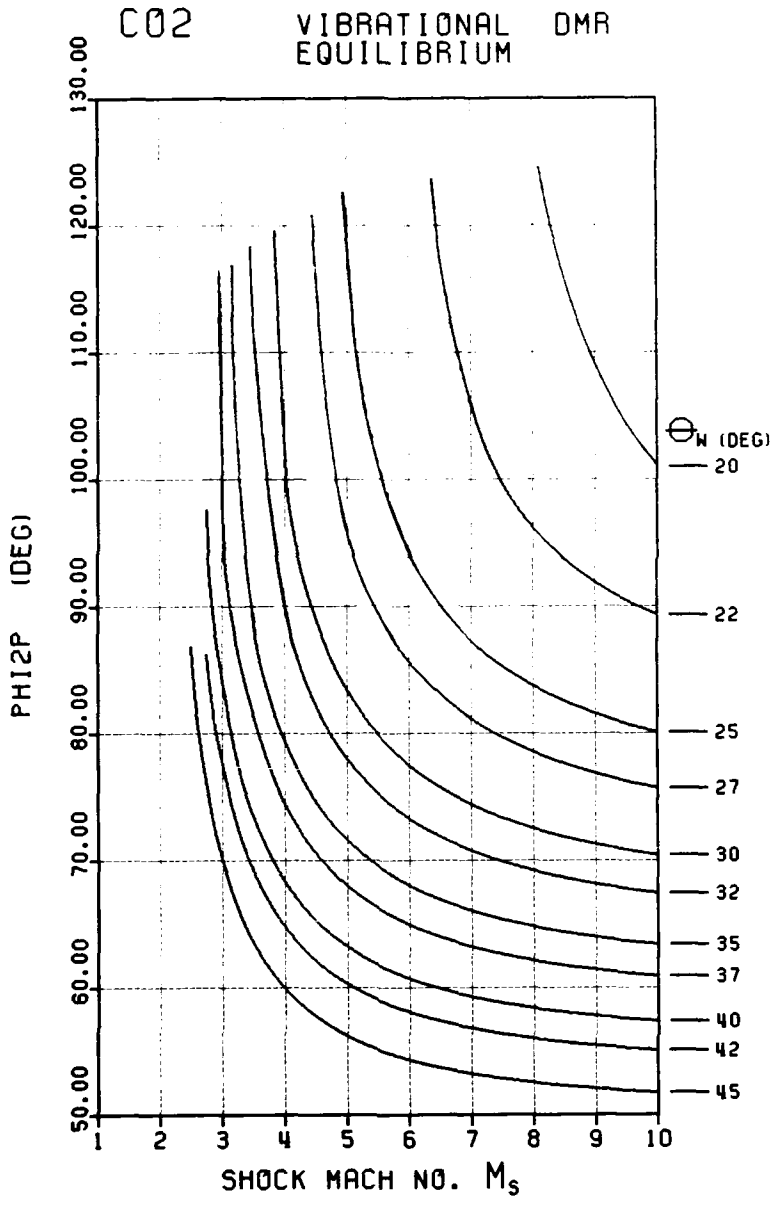

C02 VIBRATIONAL DMR
EQUILIBRIUM
MACH4P
SHOCK MACH NO. M_S
Θ_W (DEG)
20
22
25
27
30
32
35
37
40
42
45

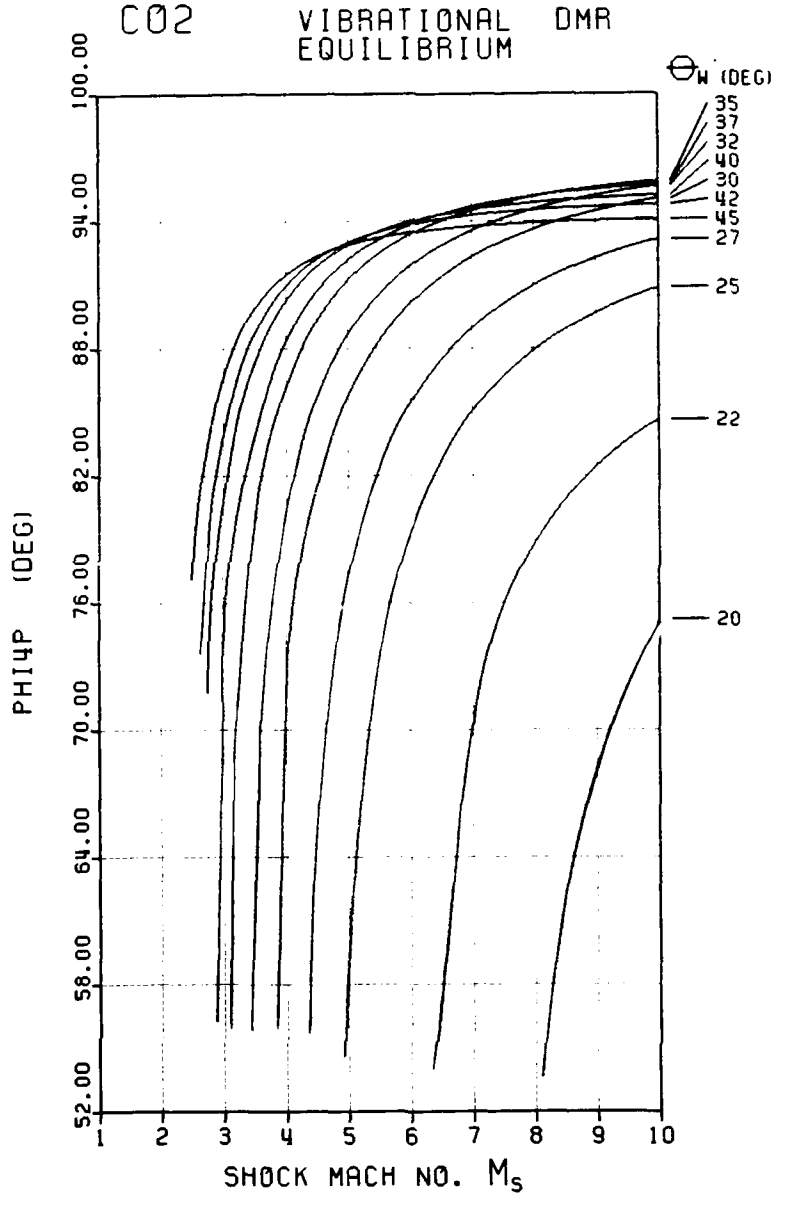

C02 VIBRATIONAL DMR
EQUILIBRIUM
MACH5P
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20

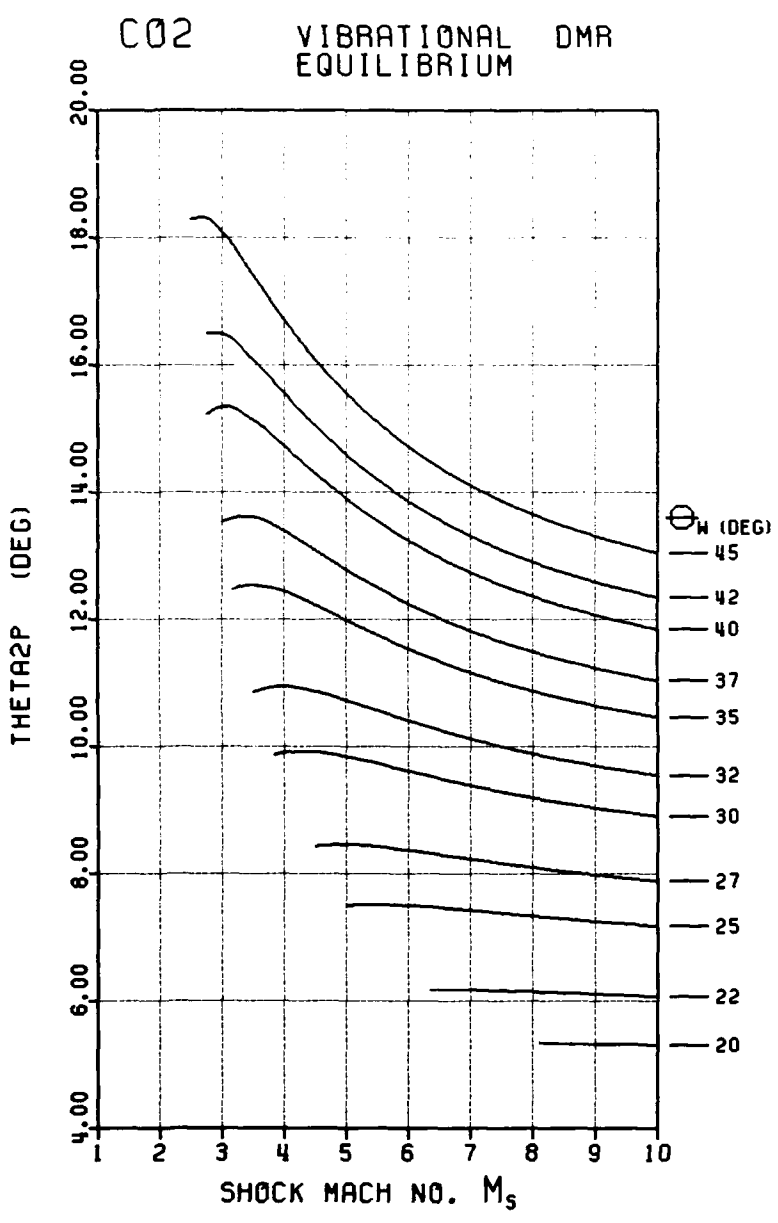

C02 VIBRATIONAL DMR
EQUILIBRIUM
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20

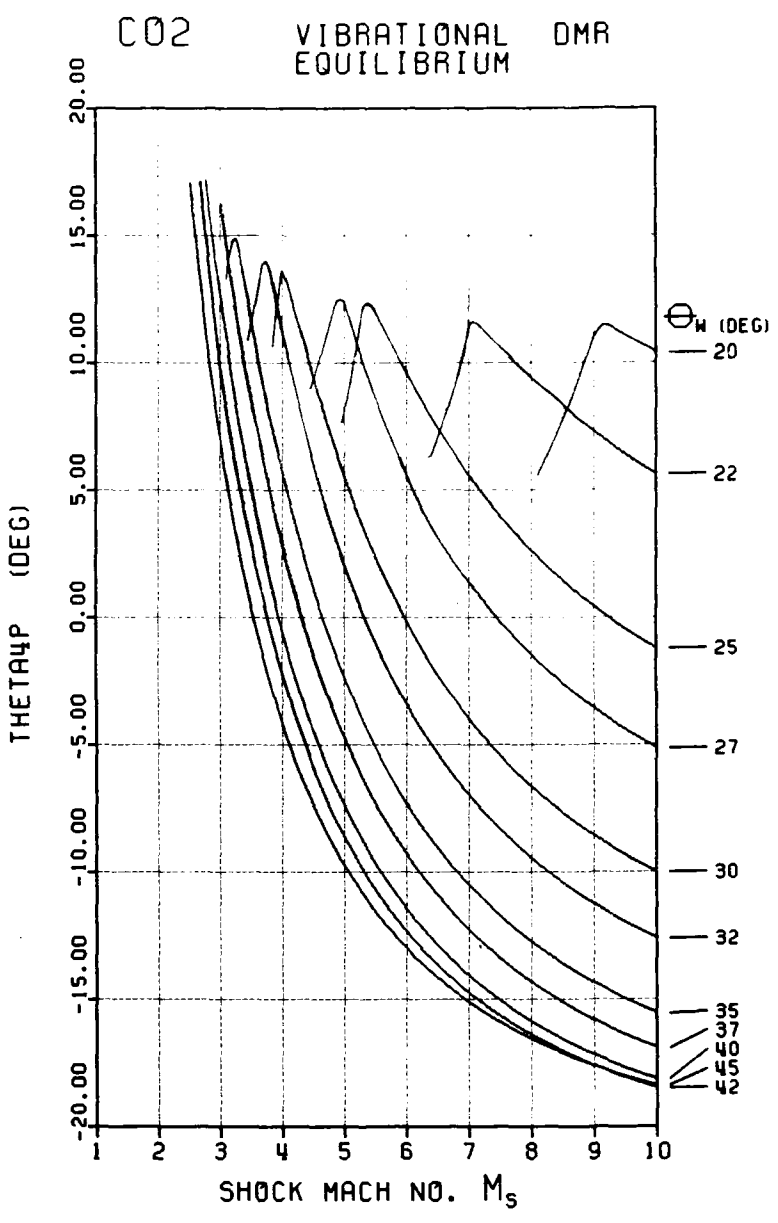

CO2 VIBRATIONAL EQUILIBRIUM DMR
AS (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20

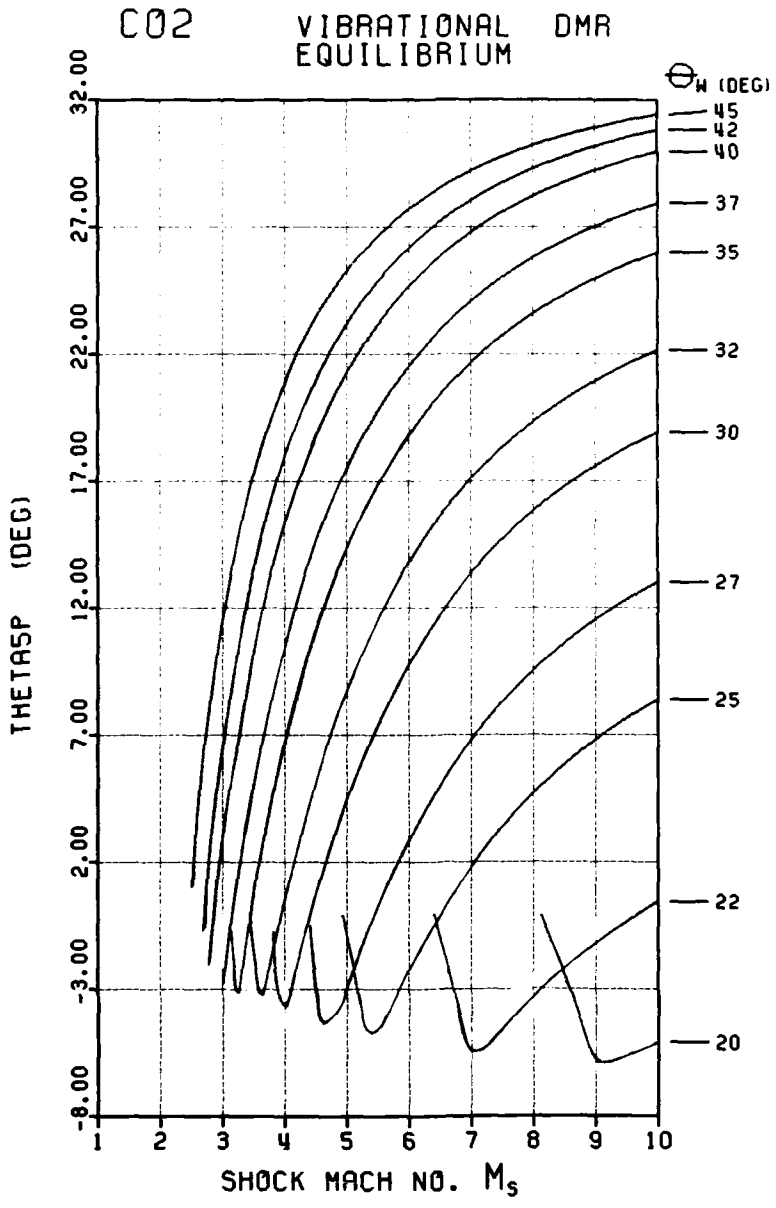

CO2 VIBRATIONAL EQUILIBRIUM DMR
PHI1P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
20
22
25
27
30
32
35
37
40
42
45

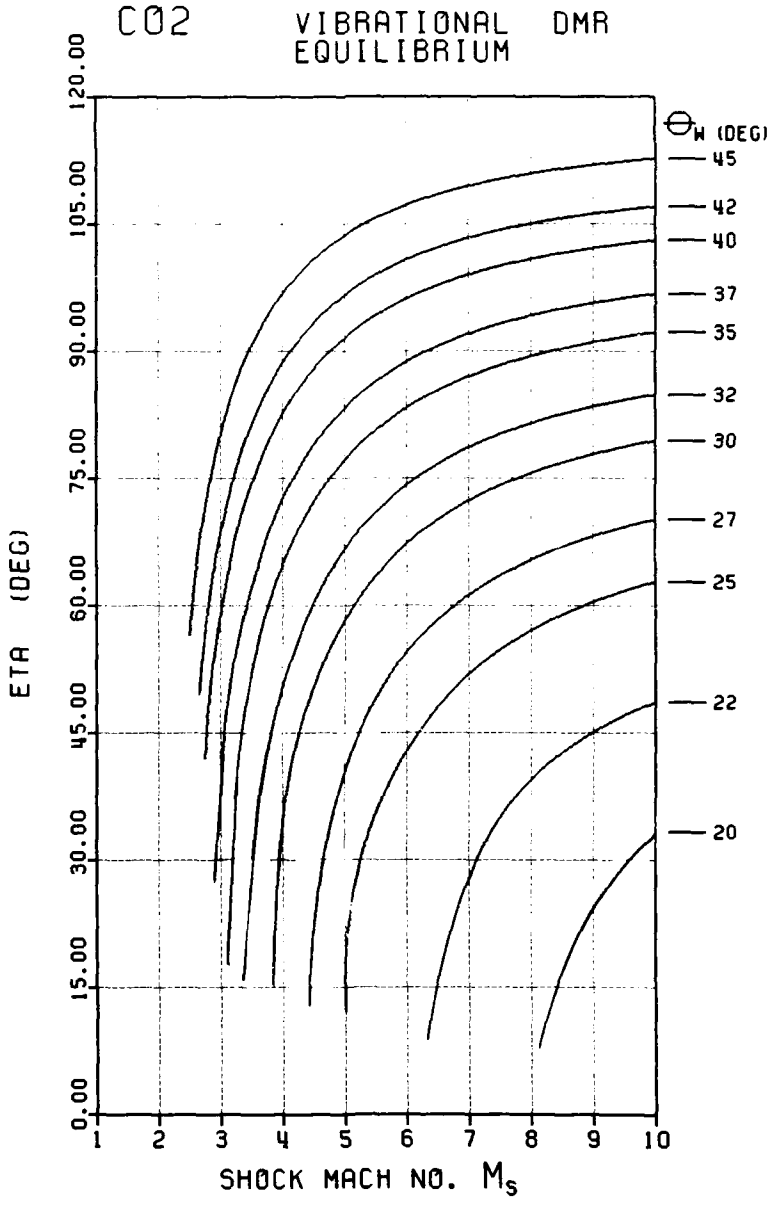

C02 VIBRATIONAL EQUILIBRIUM DMR
PHI2P (DEG)
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
20
22
25
27
30
32
35
37
40
42
45

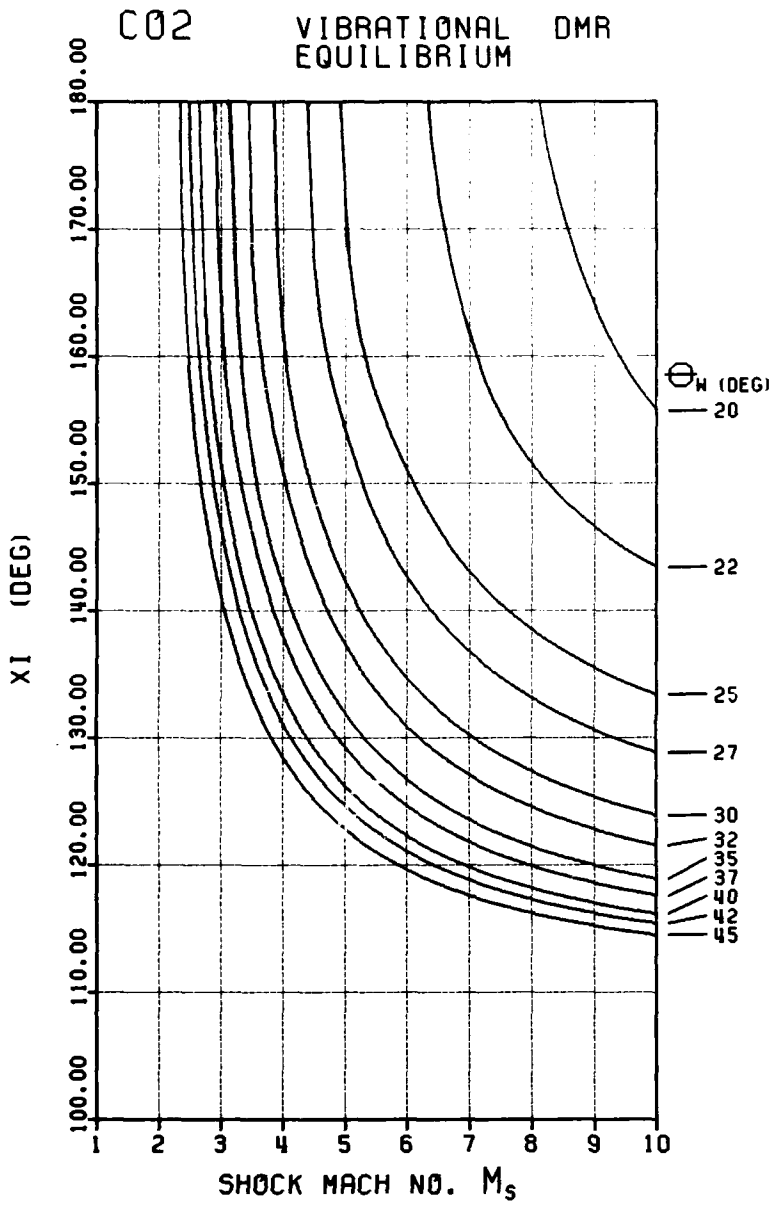

C02 VIBRATIONAL EQUILIBRIUM DMR
PHI4P (DEG)
100.00
94.00
88.00
82.00
76.00
70.00
64.00
58.00
52.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
35
37
32
40
30
42
45
27
25
22
20

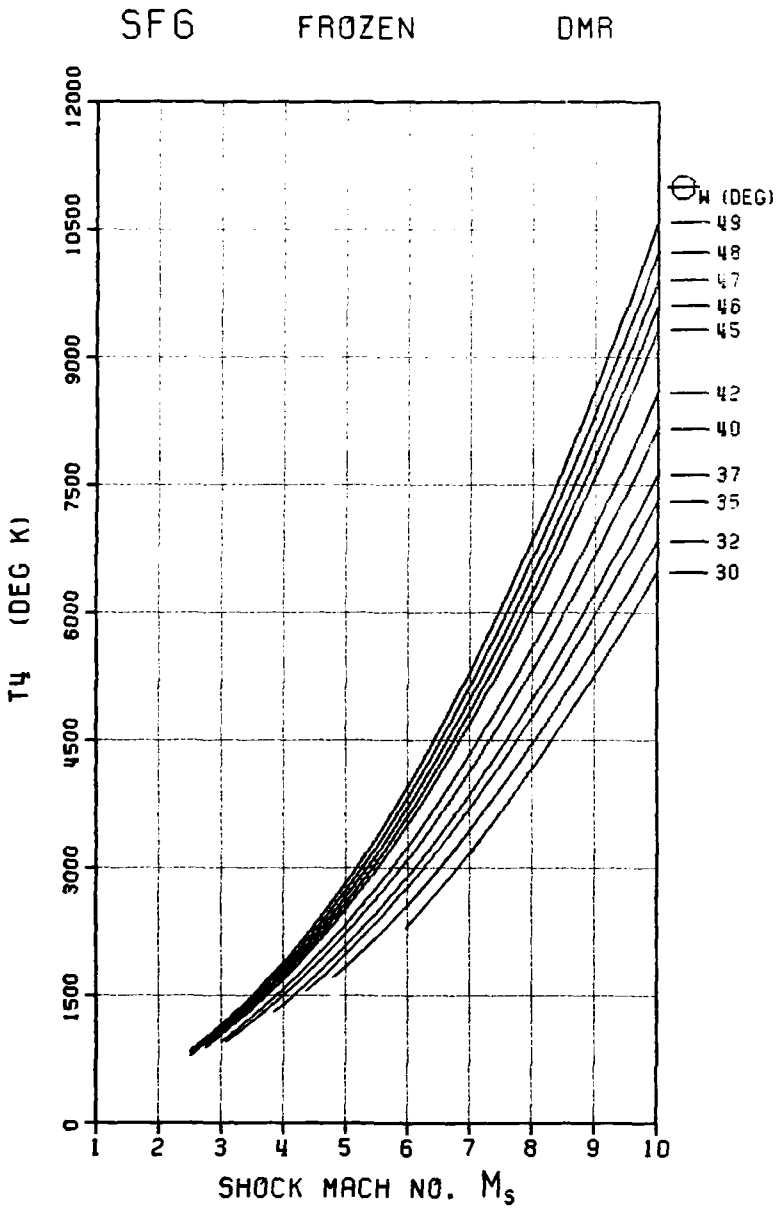

C02 VIBRATIONAL DMR EQUILIBRIUM
THETA2P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20

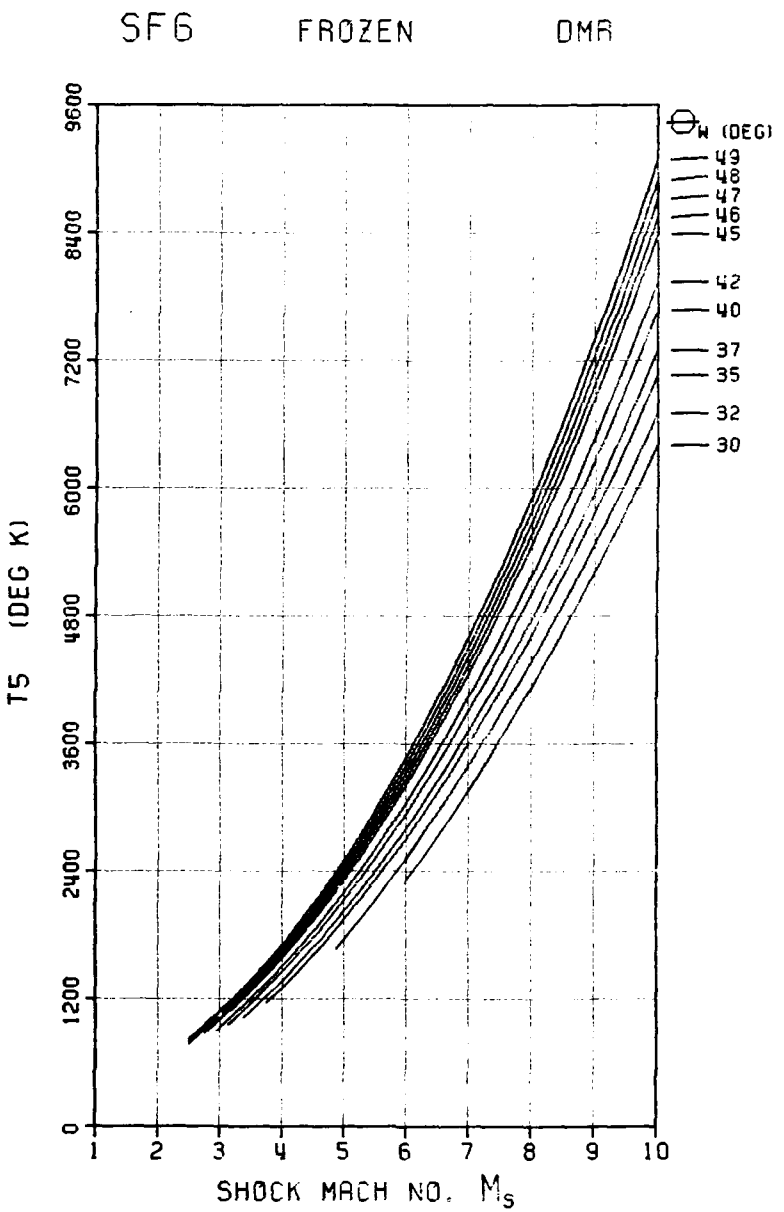

C02 VIBRATIONAL DMR EQUILIBRIUM
THETA4P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
20
22
25
27
30
32
35
37
40
45
42

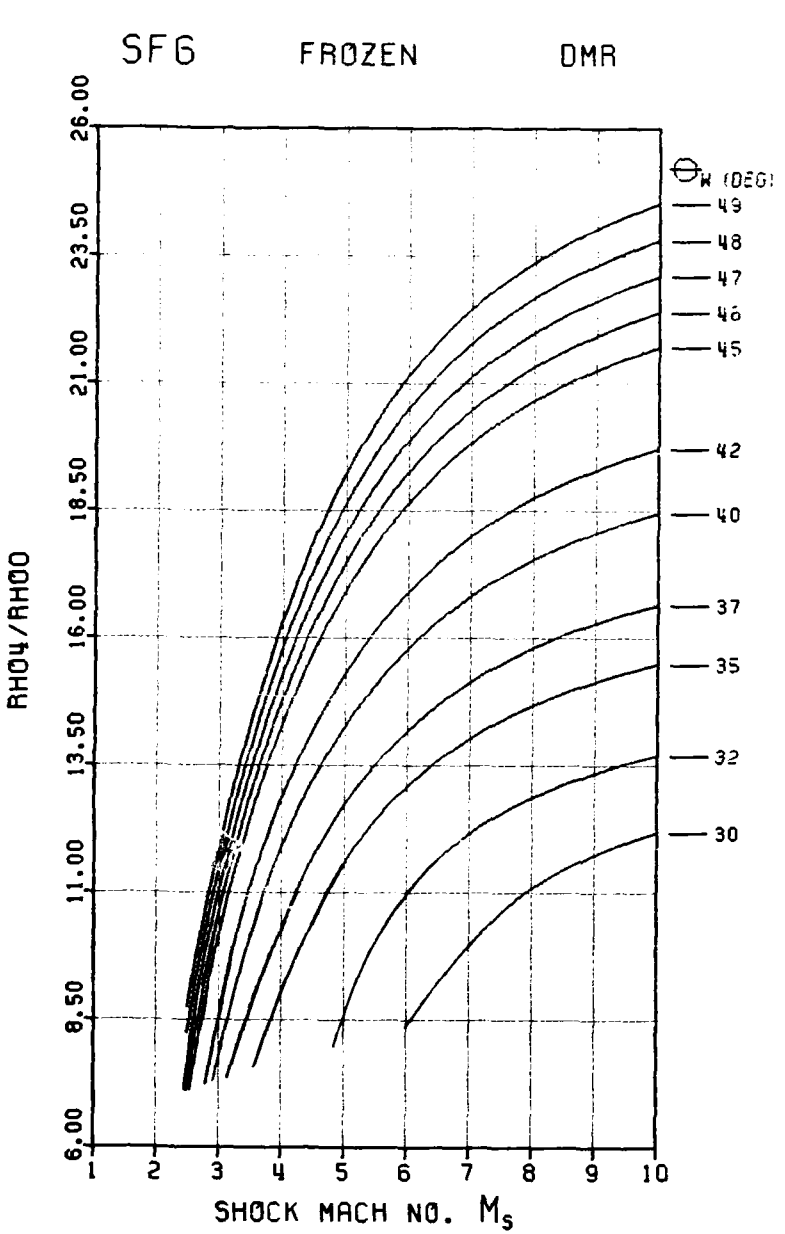

C02
VIBRATIONAL DMR
EQUILIBRIUM
THETASP (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
32.00
27.00
22.00
17.00
12.00
7.00
2.00
-3.00
-8.00
1
2
3
4
5
6
7
8
9
10

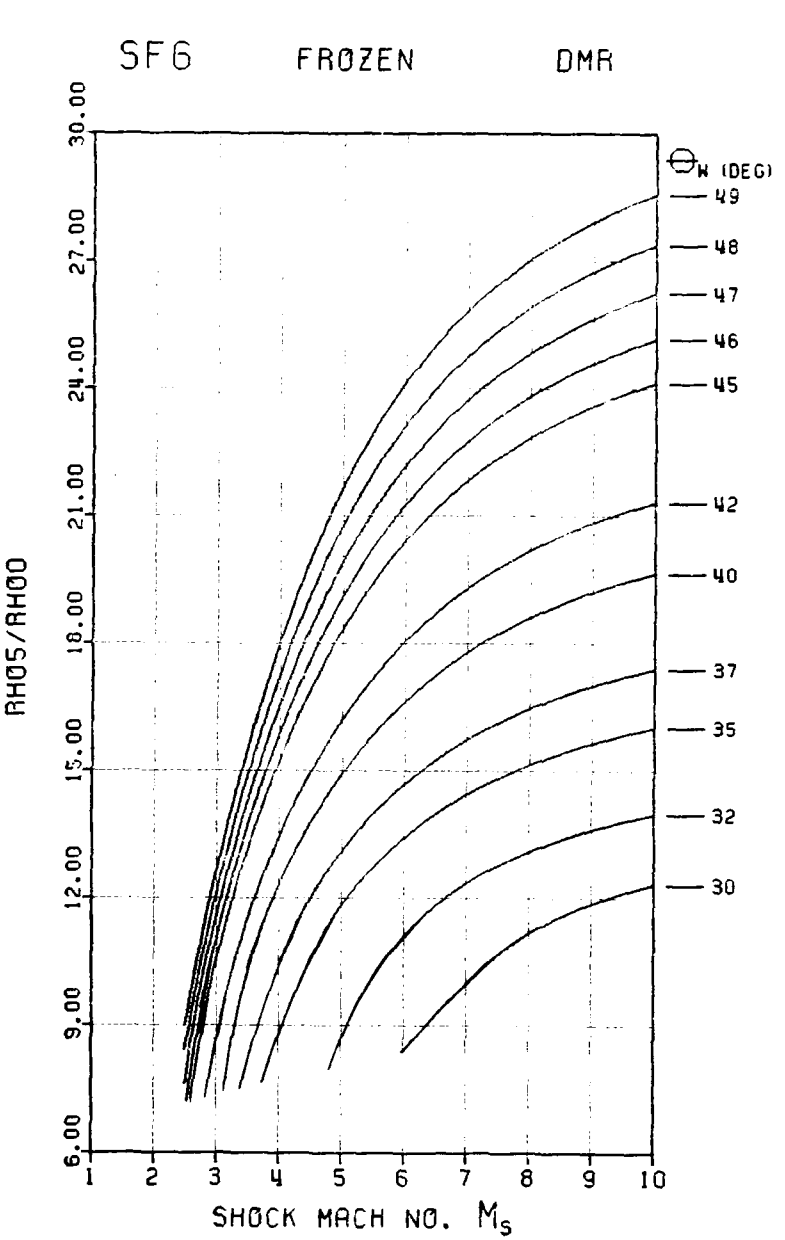

C02
VIBRATIONAL DMR
EQUILIBRIUM
ETA (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
32
30
27
25
22
20
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
1
2
3
4
5
6
7
8
9
10

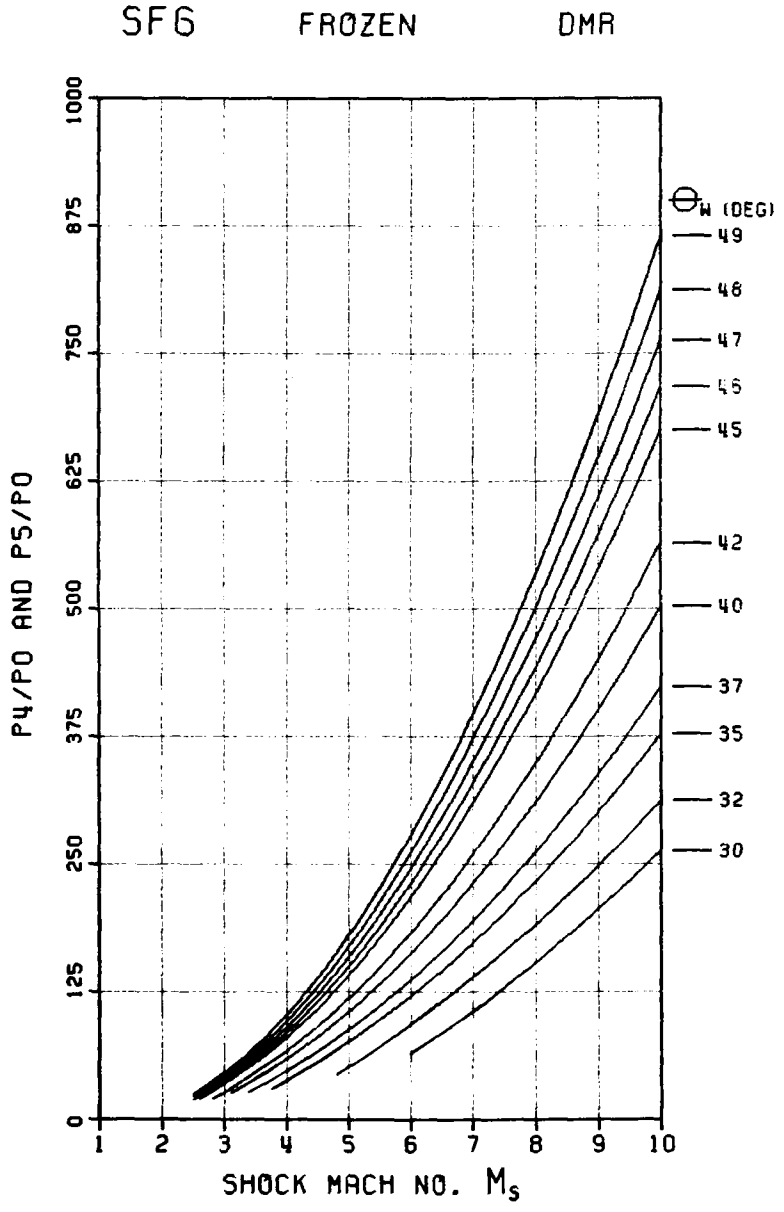

C02
VIBRATIONAL DMR
EQUILIBRIUM
XI (DEG)
180.00
170.00
160.00
150.00
140.00
130.00
120.00
110.00
100.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
20
22
25
27
30
32
35
37
40
42
45

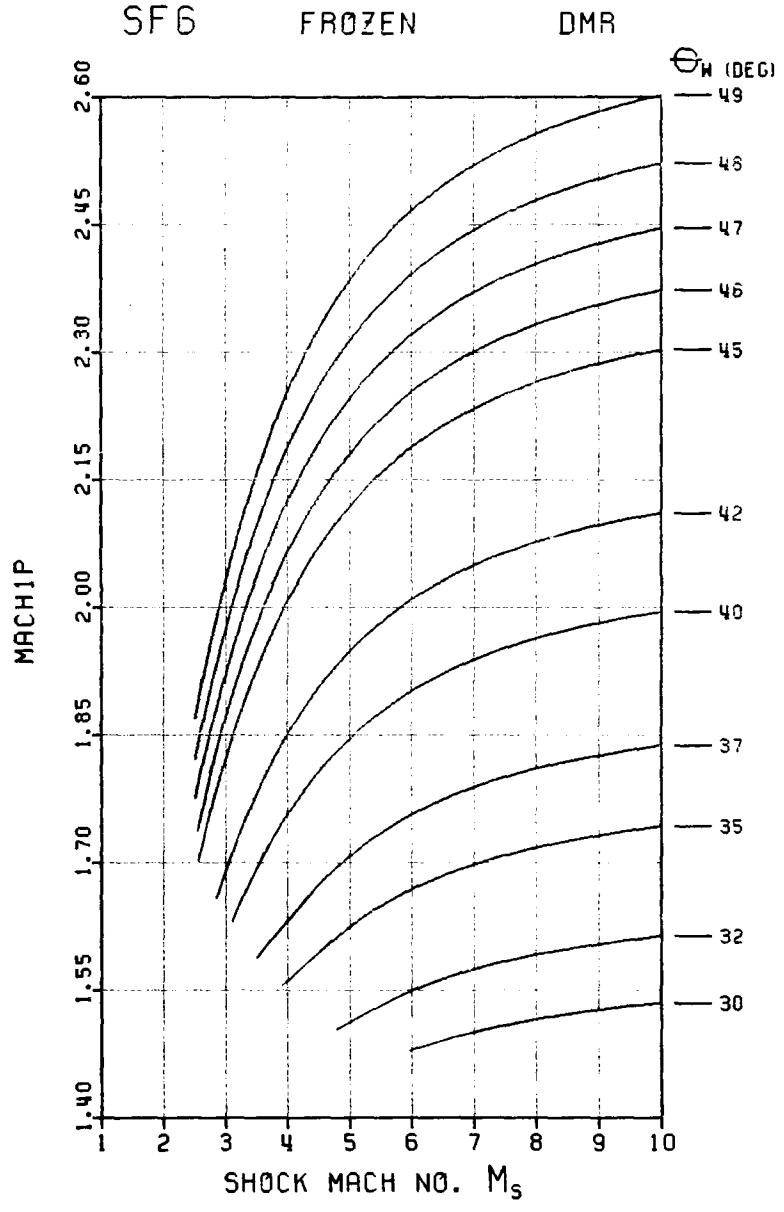

SF6 FROZEN DMR
T4 (DEG K)
0
1500
3000
4500
6000
7500
9000
10500
12000
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. Ms
θW (DEG)
49
48
47
46
45
42
40
37
35
32
30

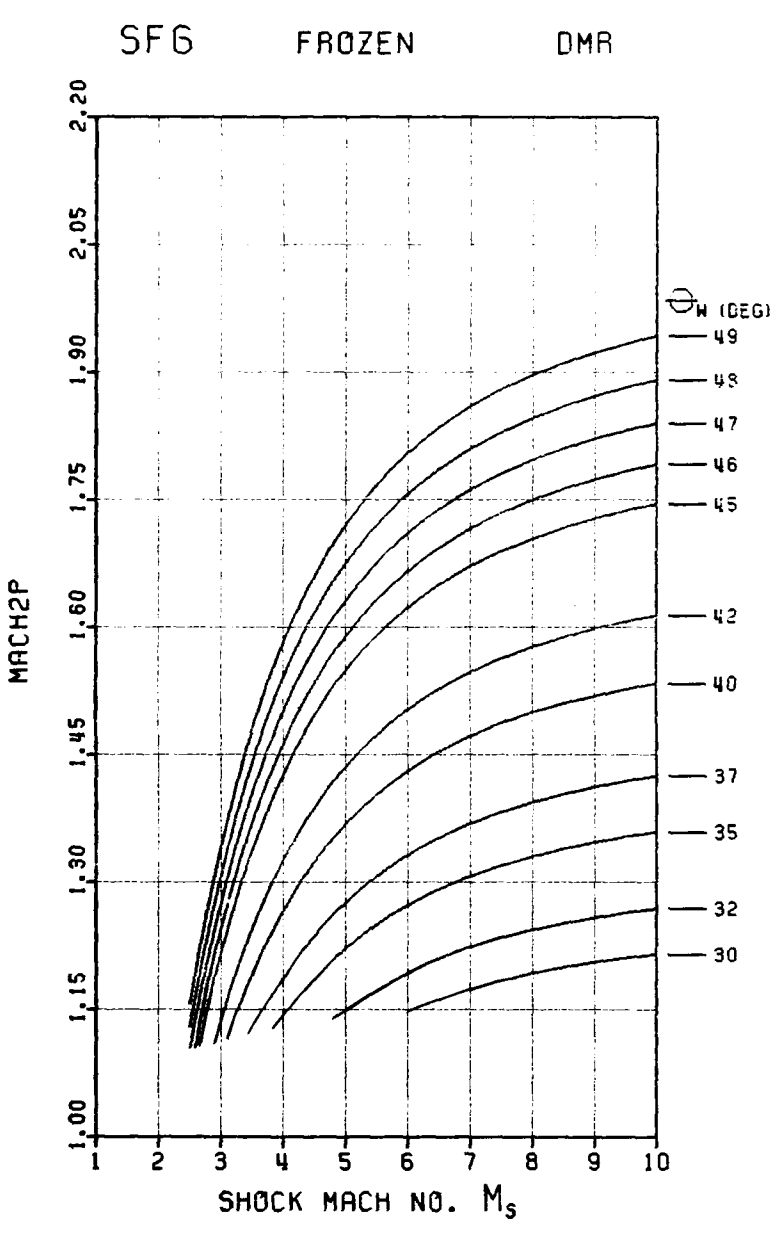

SF6 FROZEN DMR
T5 (DEG K)
0
1200
2400
3600
4800
6000
7200
8400
9600
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. Ms
θW (DEG)
49
48
47
46
45
42
40
37
35
32
30

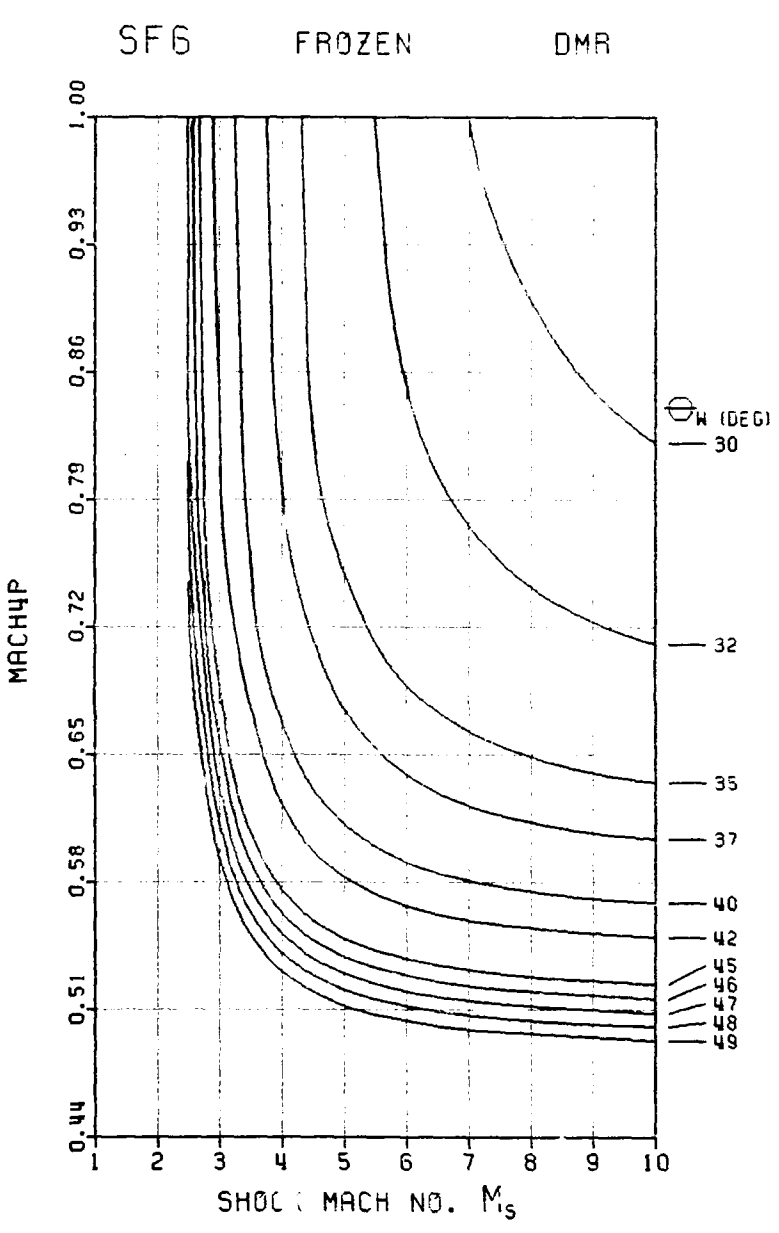

SF6 FROZEN DMR
RH04/RH00
26.00
23.50
21.00
18.50
16.00
13.50
11.00
8.50
6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30

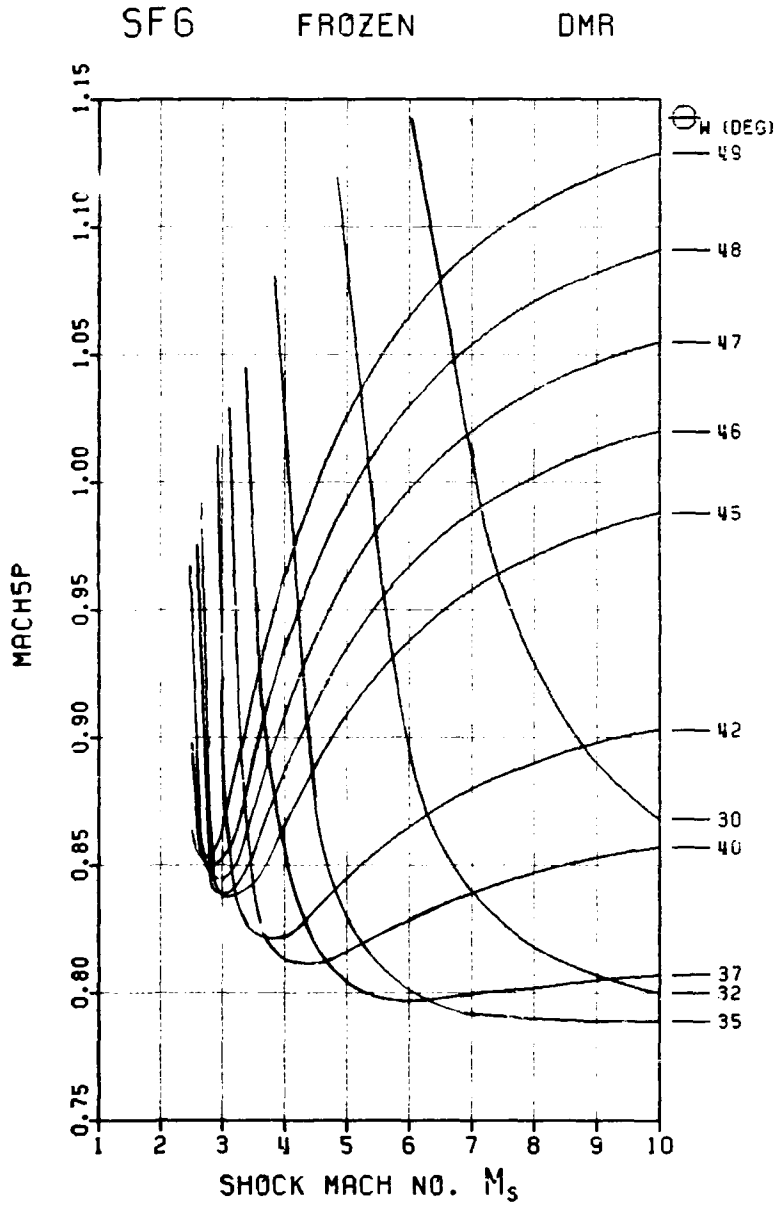

SF6 FROZEN DMR
RH05/RH00
30.00
27.00
24.00
21.00
18.00
15.00
12.00
9.00
6.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30

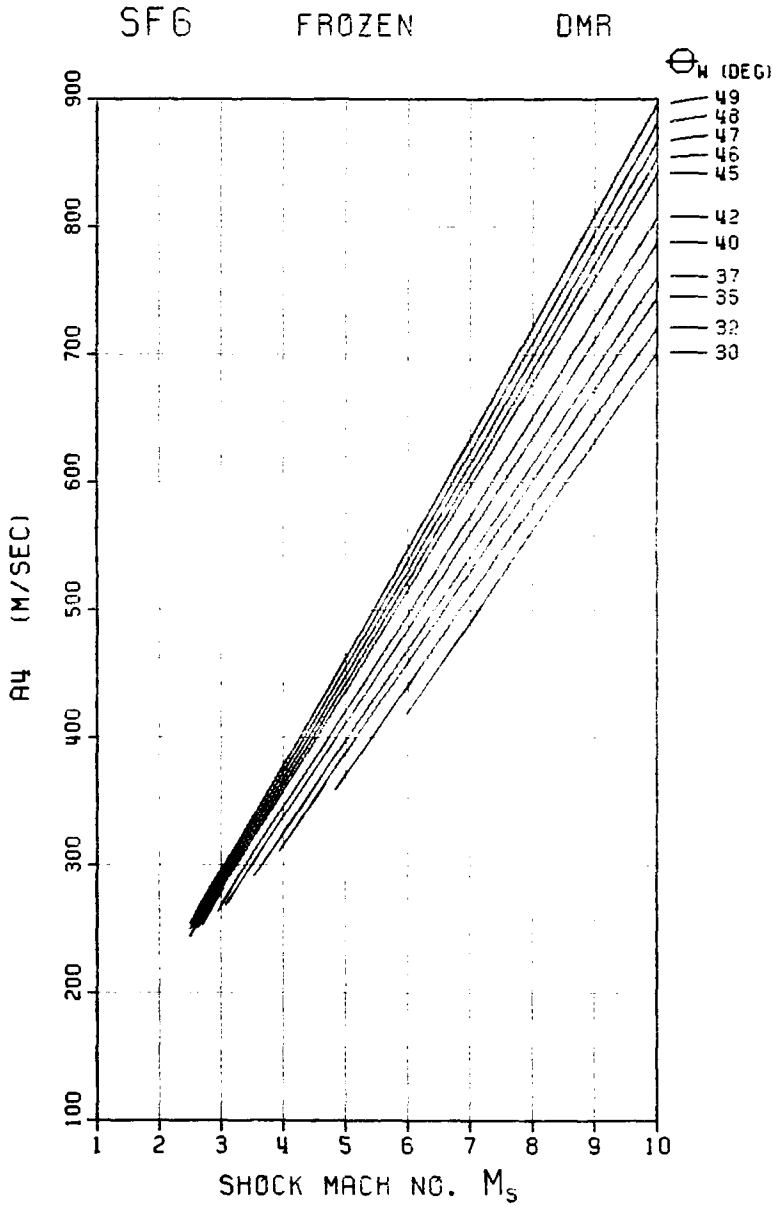

SF6 FROZEN DMR
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
0
125
250
375
500
625
750
875
1000
1
2
3
4
5
6
7
8
9
10

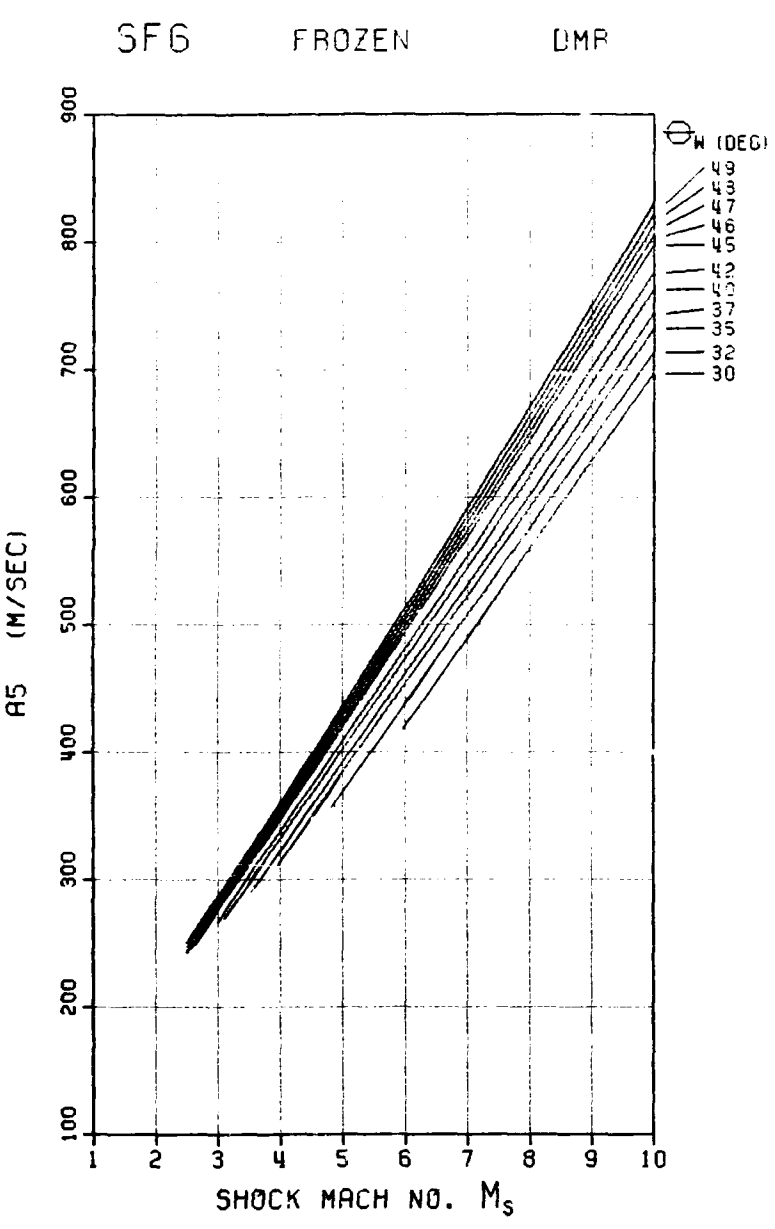

SF6 FROZEN DMR
MACH1P
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30
1.40
1.55
1.70
1.85
2.00
2.15
2.30
2.45
2.60
1
2
3
4
5
6
7
8
9
10


SF6 FROZEN DMR
MACH2P
SHOCK MACH NO. M_s
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30


SF6 FROZEN DMR
MACH4P
SHOCK MACH NO. M_s
Θ_W (DEG)
30
32
35
37
40
42
45
46
47
48
49


SF6 FROZEN DMR
MACHSP
SHOCK MACH NO. M_S
θ_W (DEG)
49
48
47
46
45
42
30
40
37
32
35


SF6 FROZEN DMR
A4 (M/SEC)
SHOCK MACH NO. M_S
θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30


SF6 FROZEN DMR
A5 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
100
200
300
400
500
600
700
800
900
1
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3
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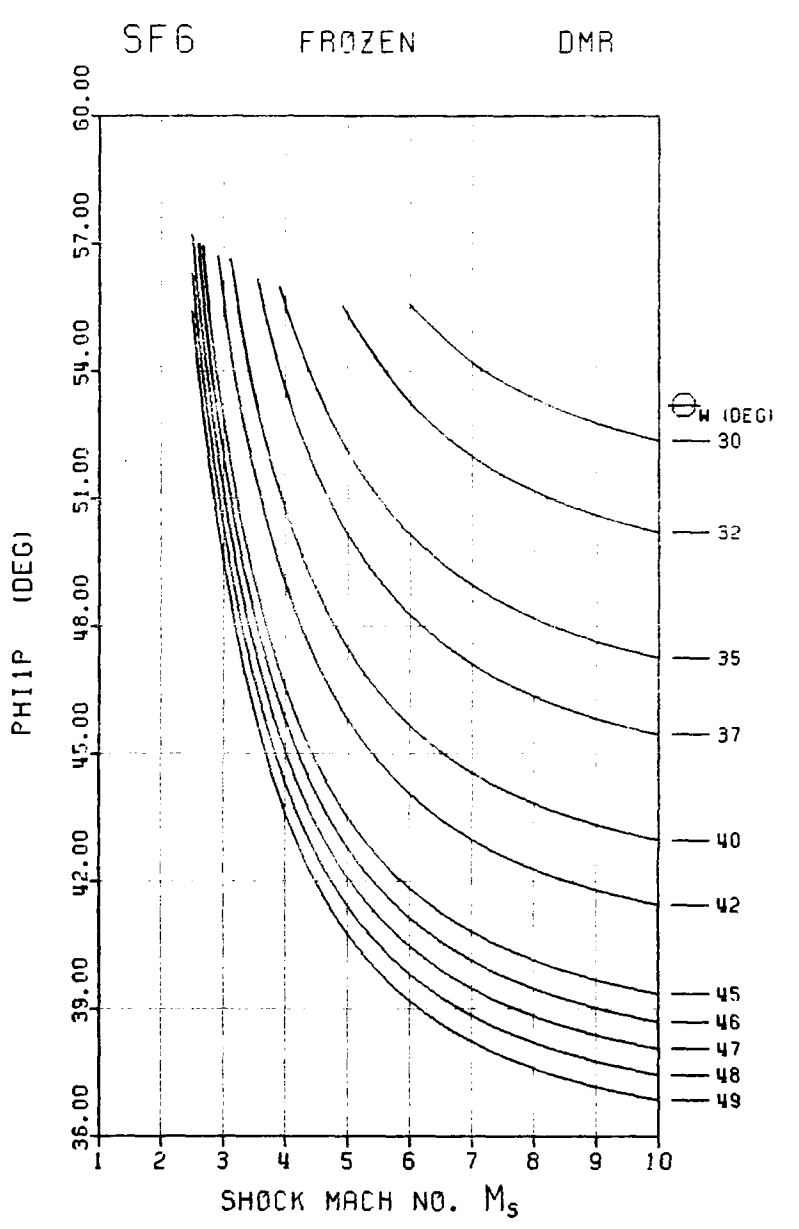
10


SF6 FROZEN DMR
PHI1P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
30
32
35
37
40
42
45
46
47
48
49
36.00
39.00
42.00
45.00
48.00
51.00
54.00
57.00
60.00
1
2
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10

AD-A164 047 TABULAR AND GRAPICAL SOLUTIONS OF REGULAR AND MACH REFLECTIONS IN PSEUDO-.. (U) TORONTO UNIV DOWNSVIEW (ONTARIO) INST FOR AEROSPACE STUDIES T C HU ET AL. 3/3

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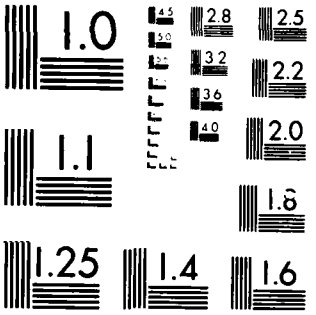
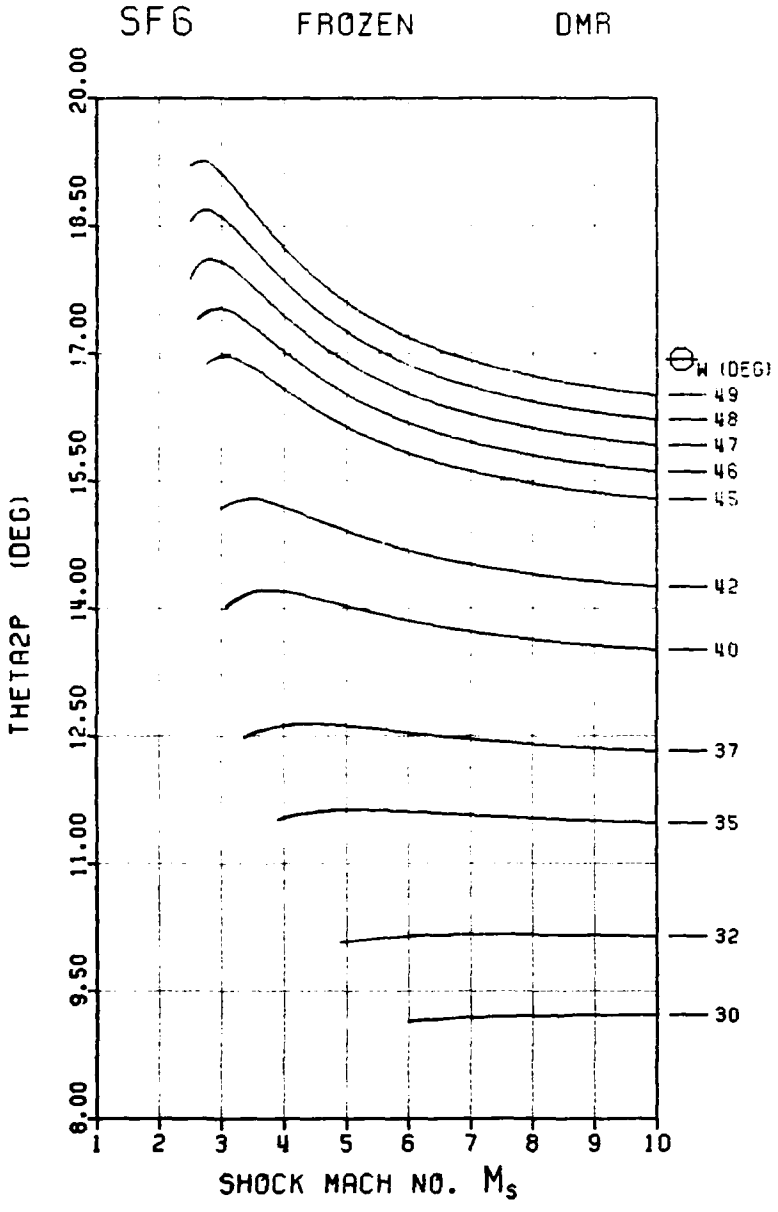
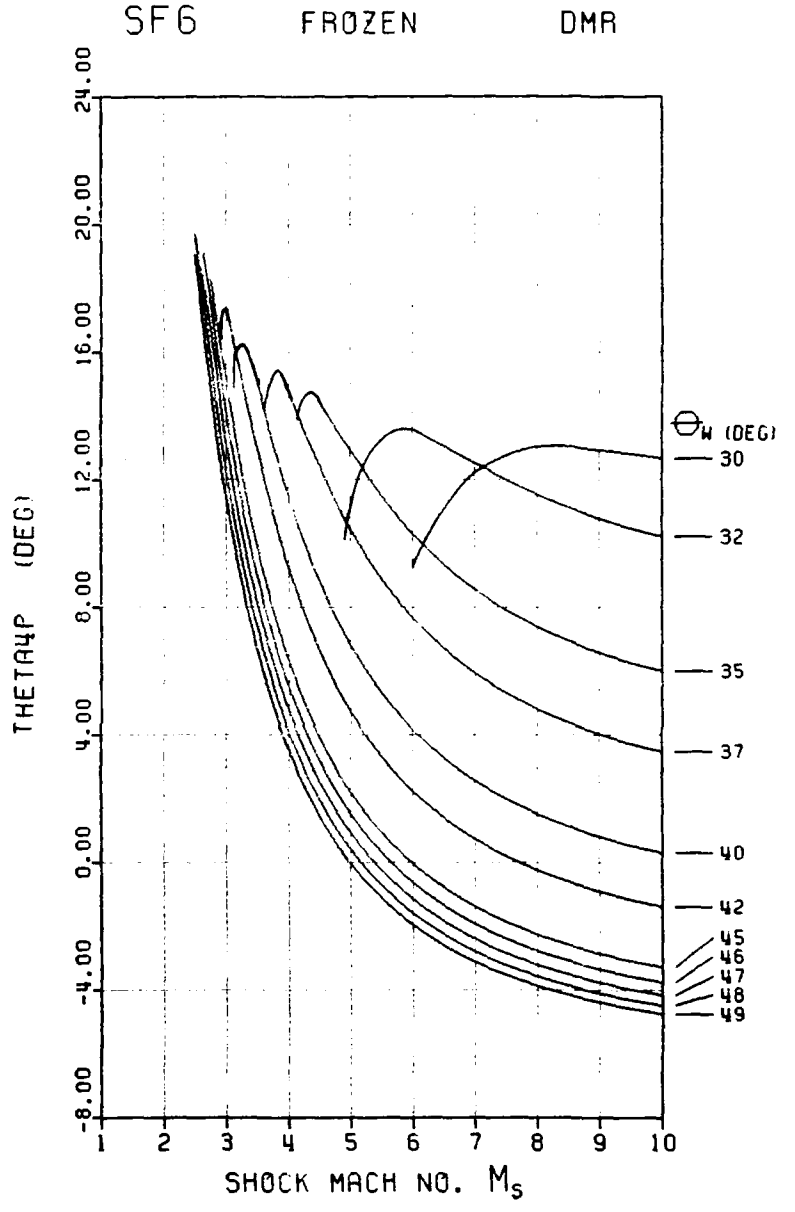
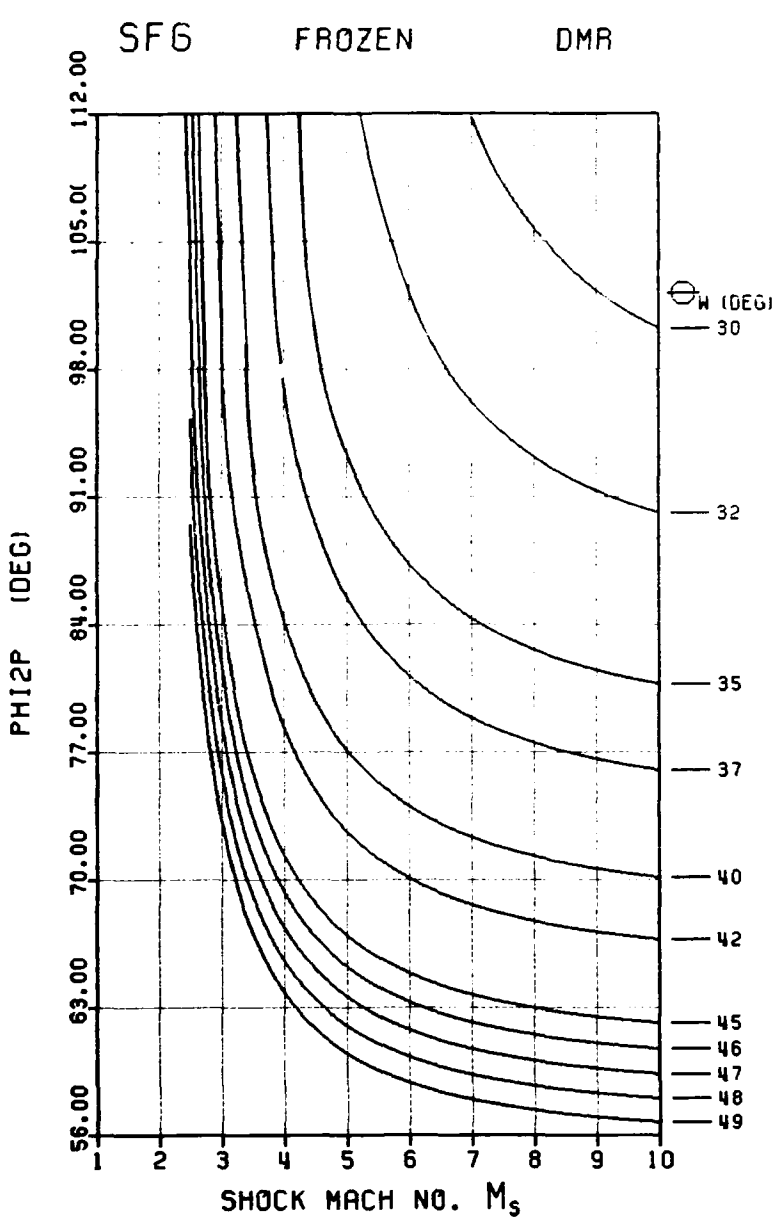
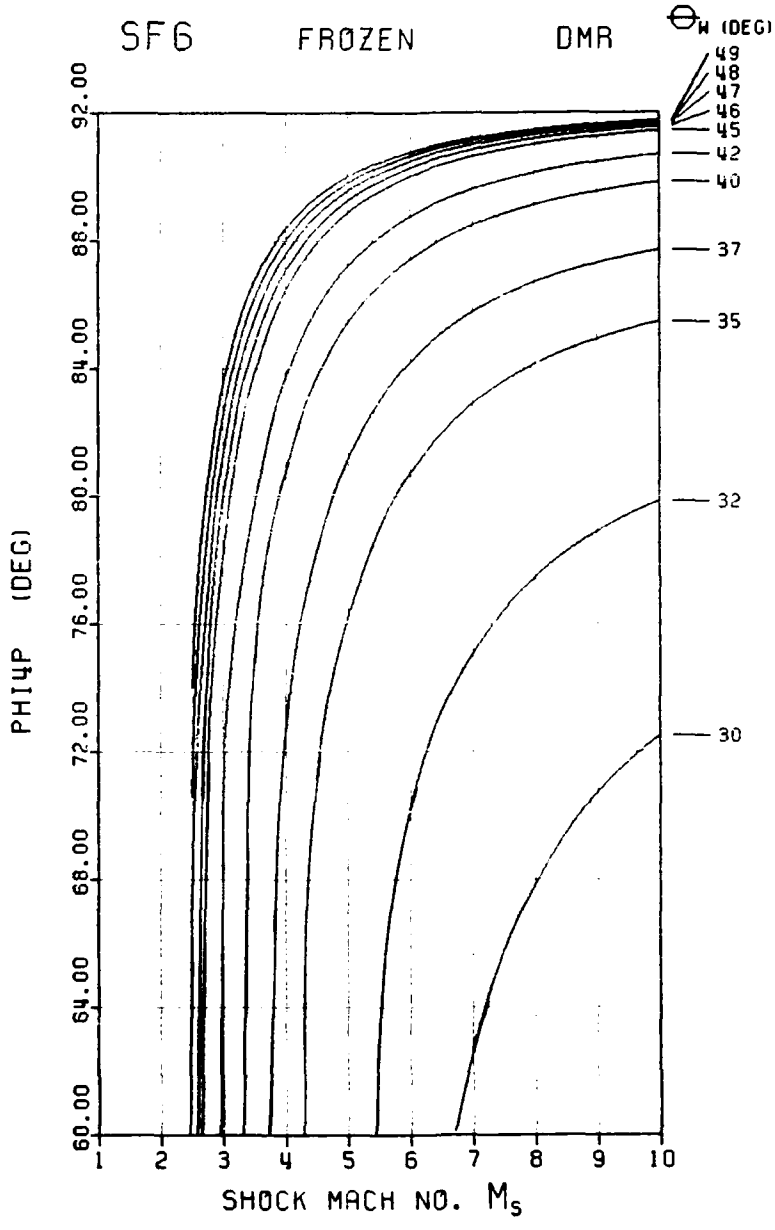
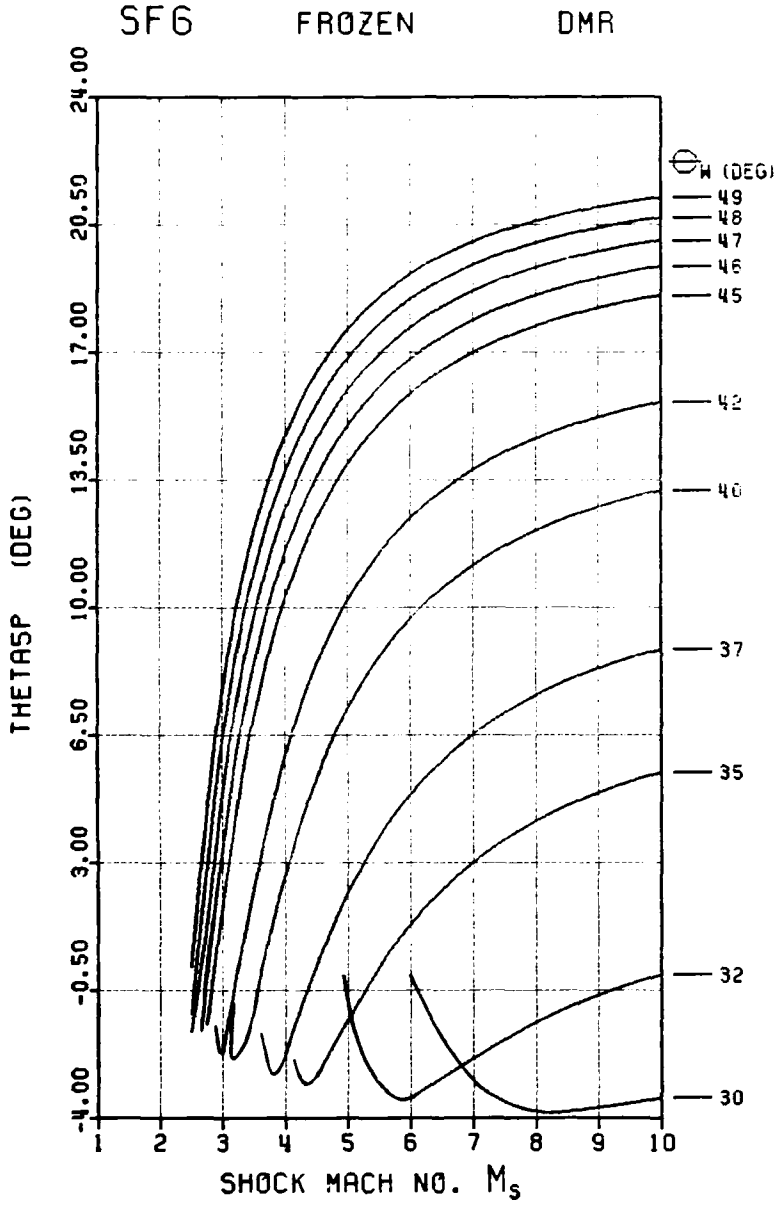


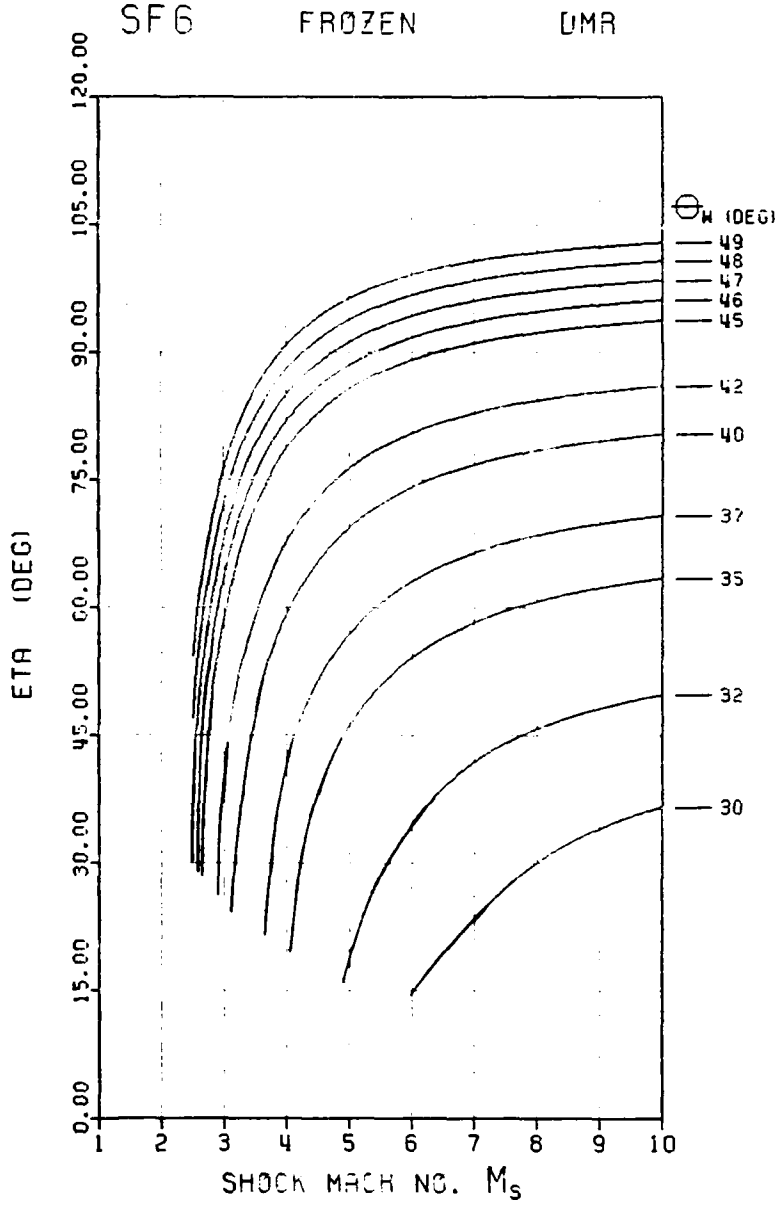

SF6 FROZEN DMR
THETA2P (DEG)
SHOCK MACH NO. M_s
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30

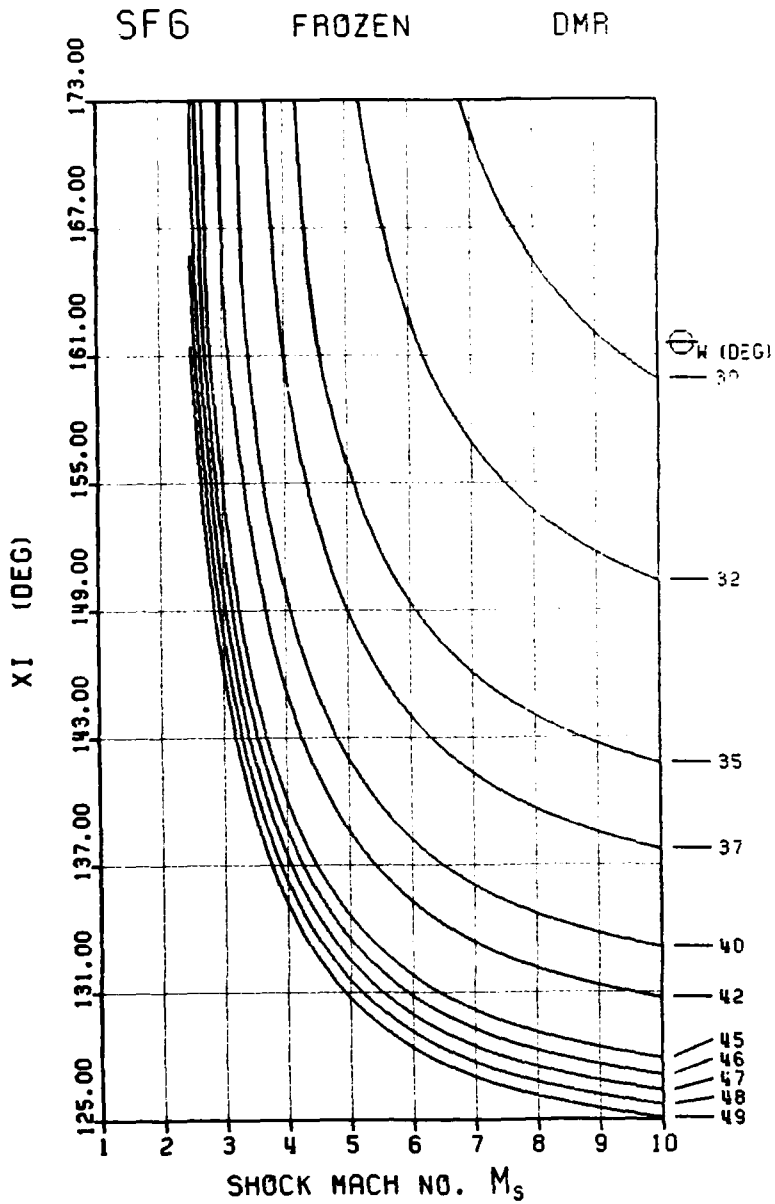

SF6 FROZEN DMR
THETA4P (DEG)
SHOCK MACH NO. M_s
Θ_W (DEG)
30
32
35
37
40
42
45
46
47
48
49

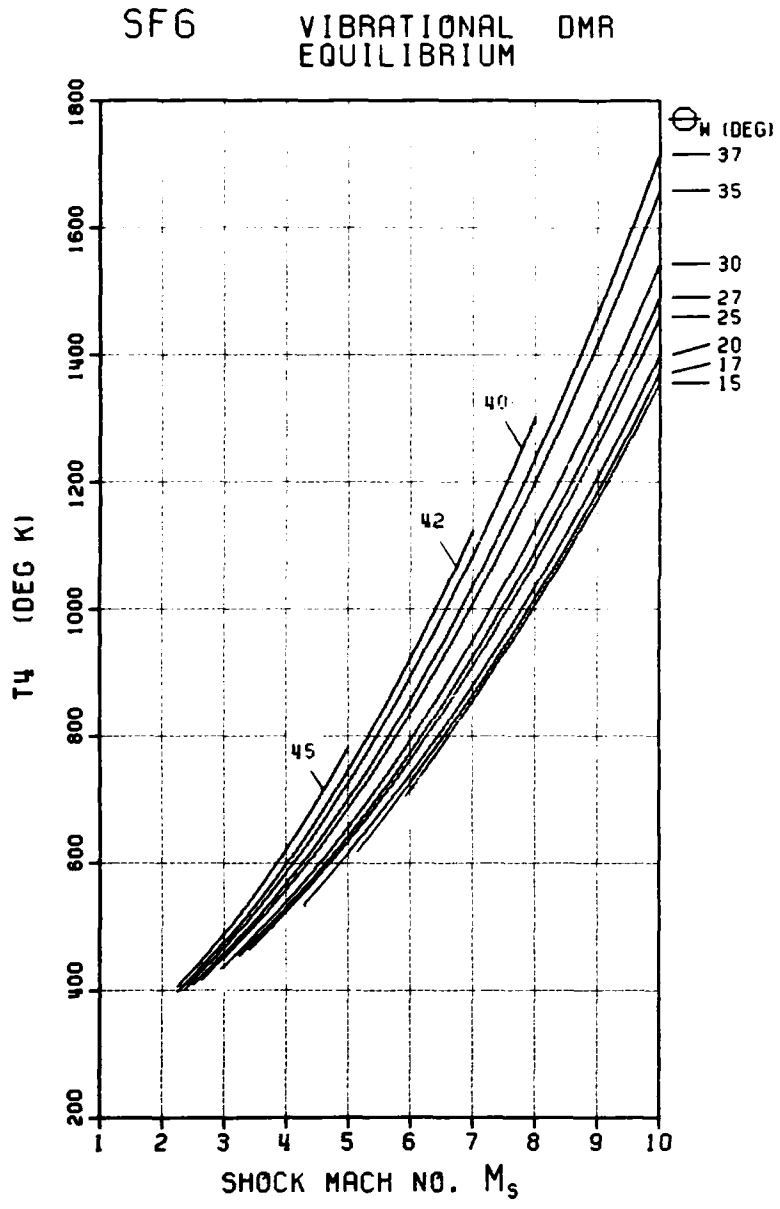

SF6 FROZEN DMR
PHI2P (DEG)
112.00
105.00
98.00
91.00
84.00
77.00
70.00
63.00
56.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
30
32
35
37
40
42
45
46
47
48
49

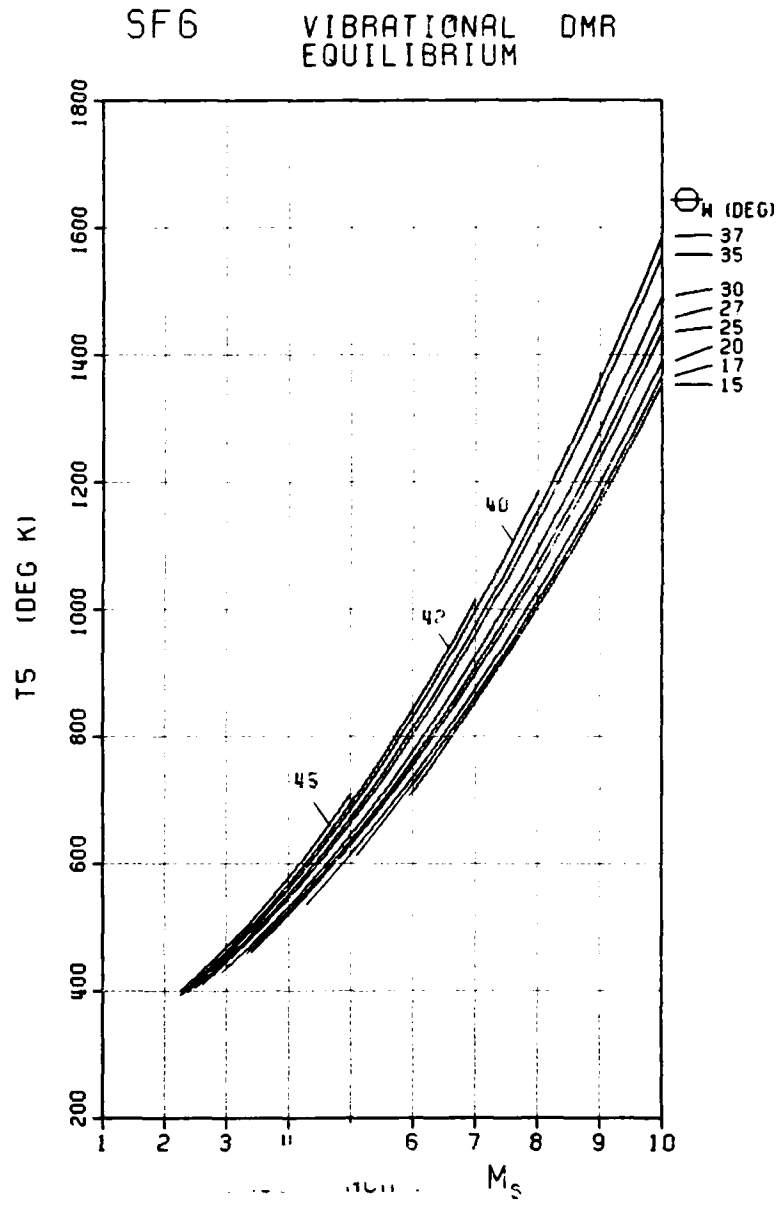

SF6 FROZEN DMR
PHI4P (DEG)
92.00
88.00
84.00
80.00
76.00
72.00
68.00
64.00
60.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
49
48
47
46
45
42
40
37
35
32
30

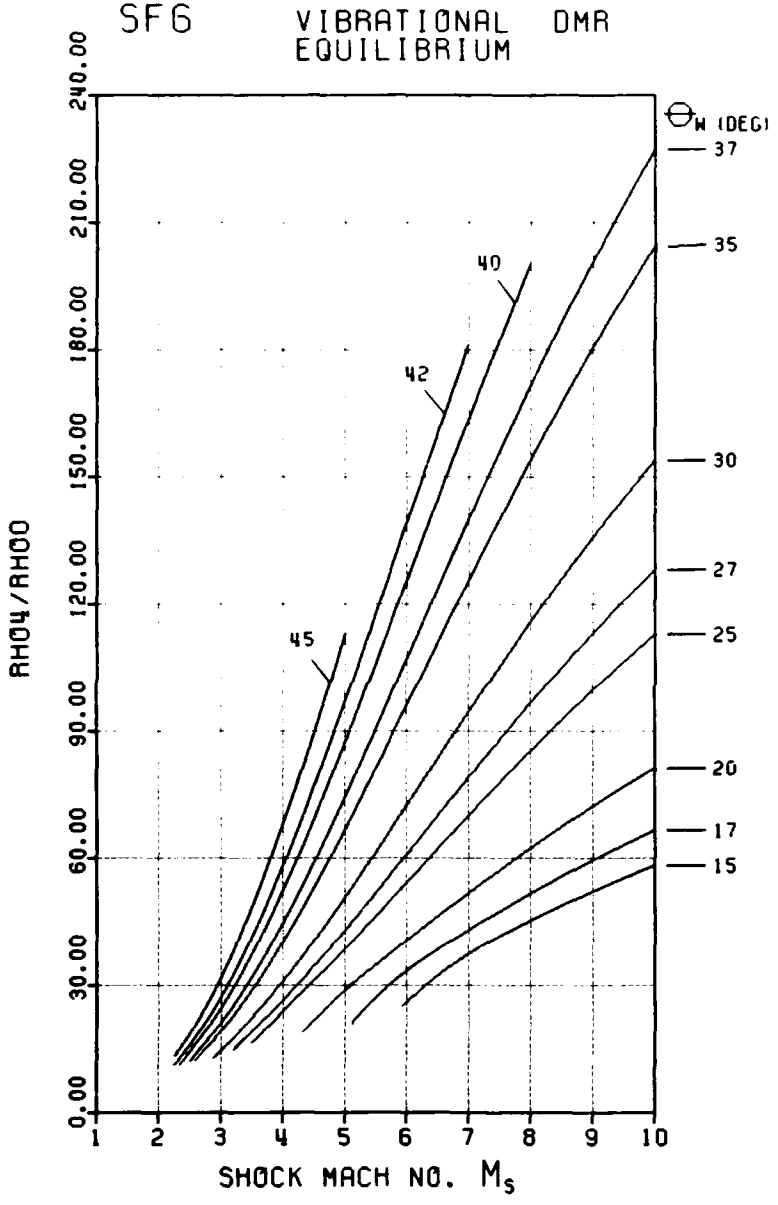

SF6 FROZEN DMR
THETASP (DEG)
24.00
20.50
17.00
13.50
10.00
6.50
3.00
-0.50
-4.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
49
48
47
46
45
42
40
37
35
32
30

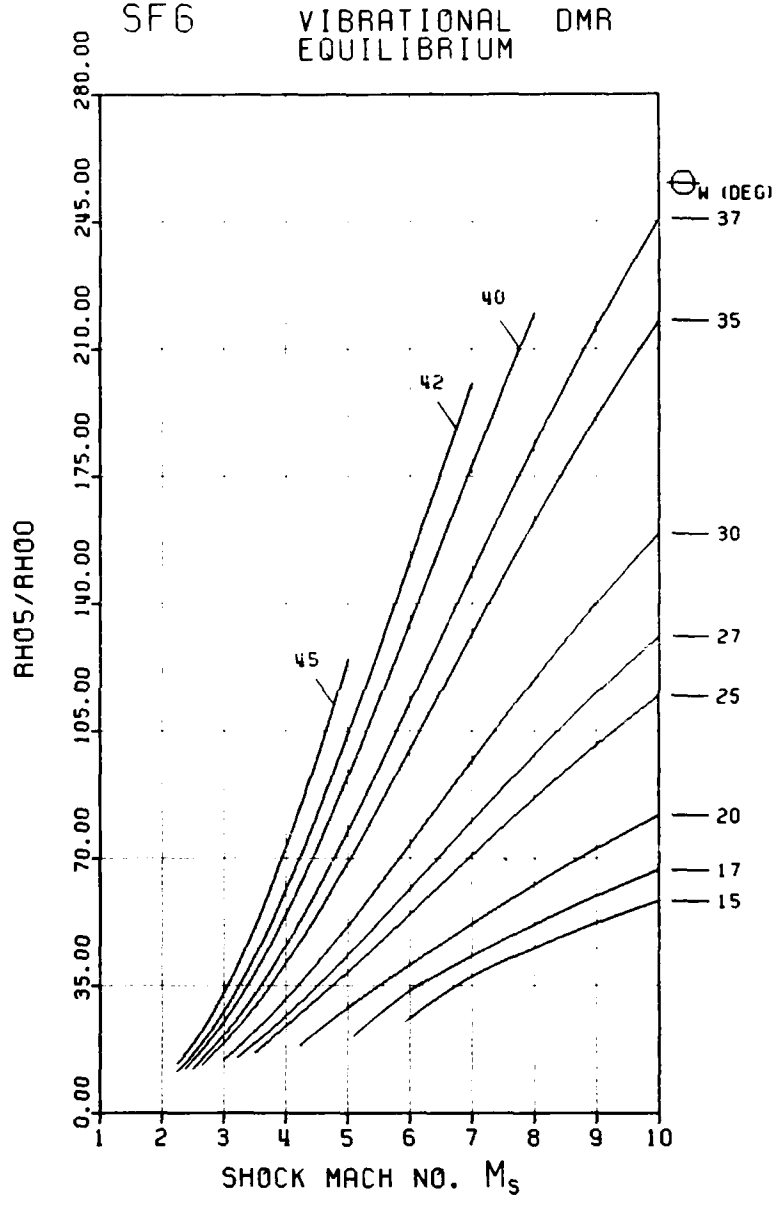

SF6 FROZEN DMR
ETA (DEG)
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_s
Θ_w (DEG)
49
48
47
46
45
42
40
37
35
32
30

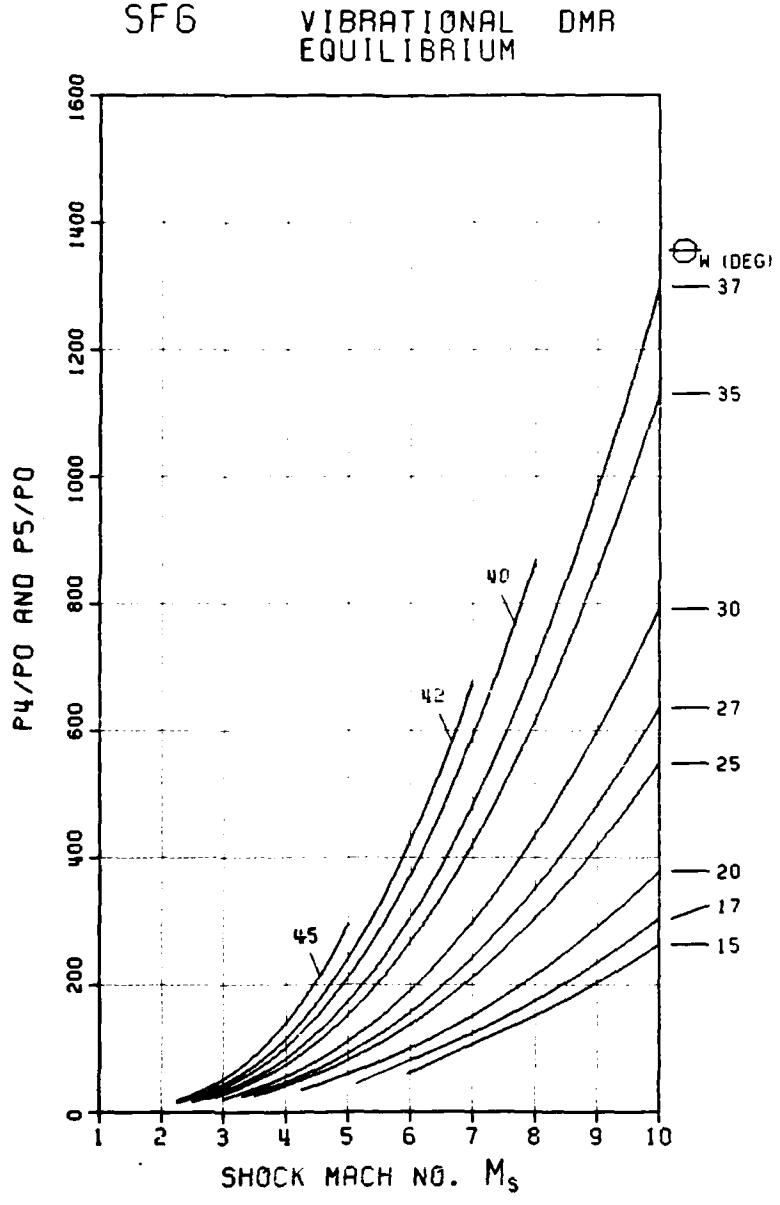

SF6 FROZEN DMR
XI (DEG)
173.00
167.00
161.00
155.00
149.00
143.00
137.00
131.00
125.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
30
32
35
37
40
42
45
46
47
48
49

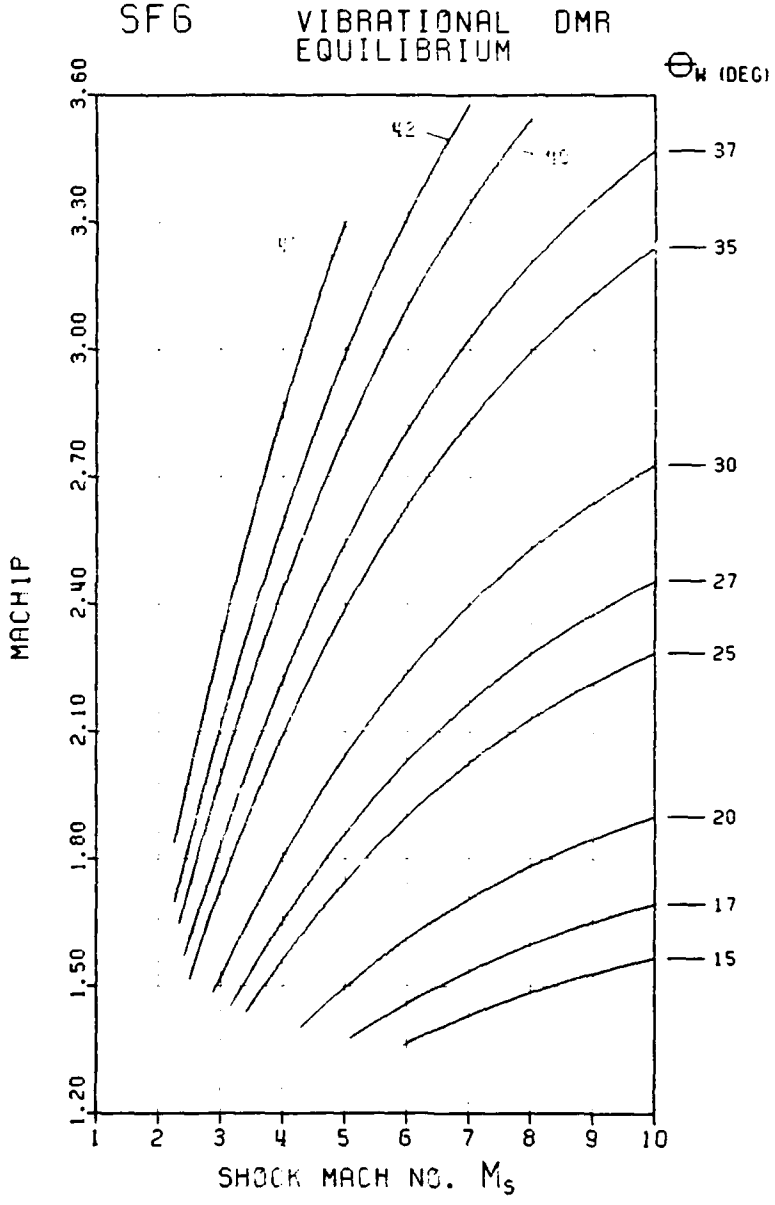

SF6 VIBRATIONAL DMR EQUILIBRIUM
T4 (DEG K)
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
40
42
45
200
400
600
800
1000
1200
1400
1600
1800
1
2
3
4
5
6
7
8
9
10

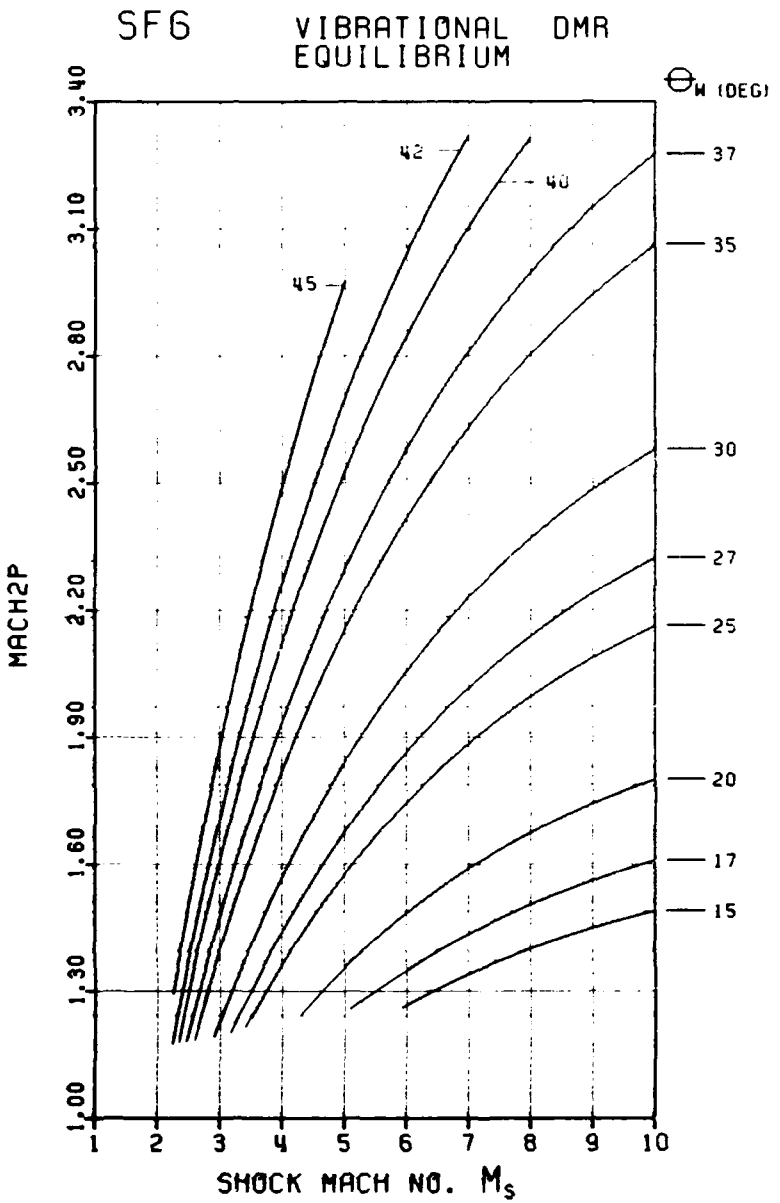

SF6 VIBRATIONAL DMR EQUILIBRIUM
T5 (DEG K)
M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
40
42
45
200
400
600
800
1000
1200
1400
1600
1800
1
2
3
6
7
8
9
10

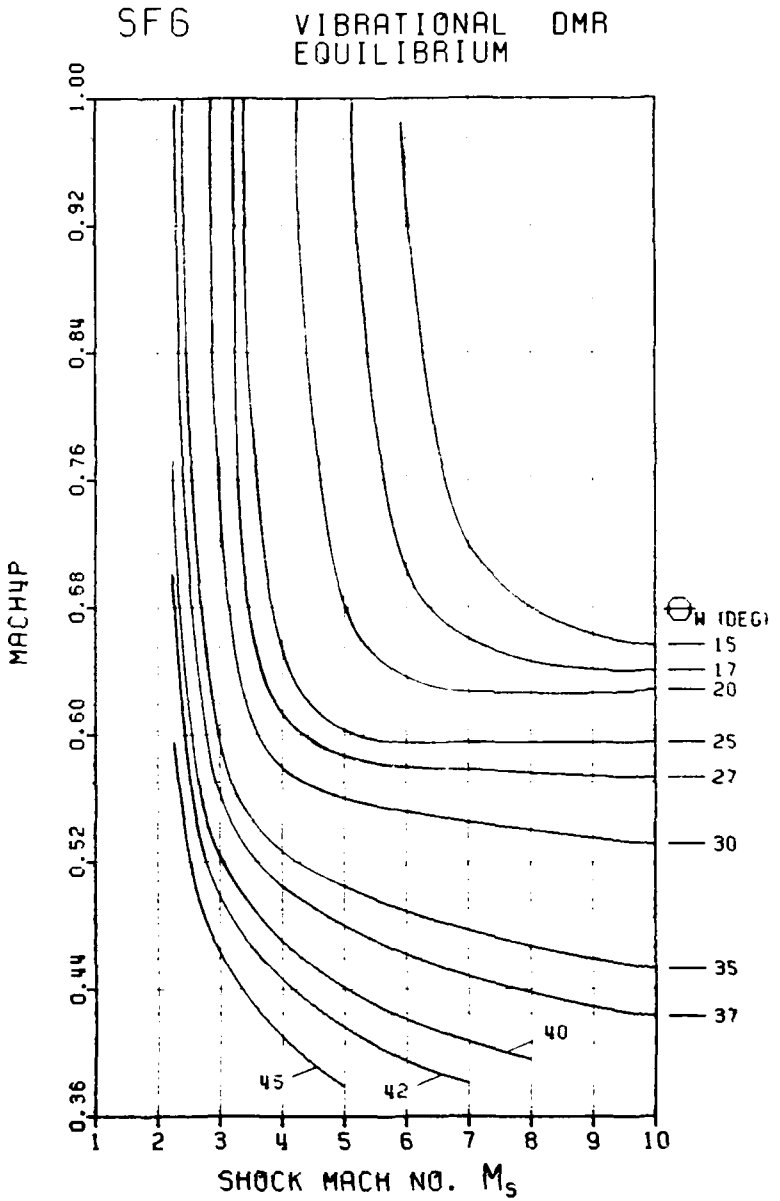

SF6 VIBRATIONAL DMR
EQUILIBRIUM
RHO4/RHOO
0.00
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
45
42
40

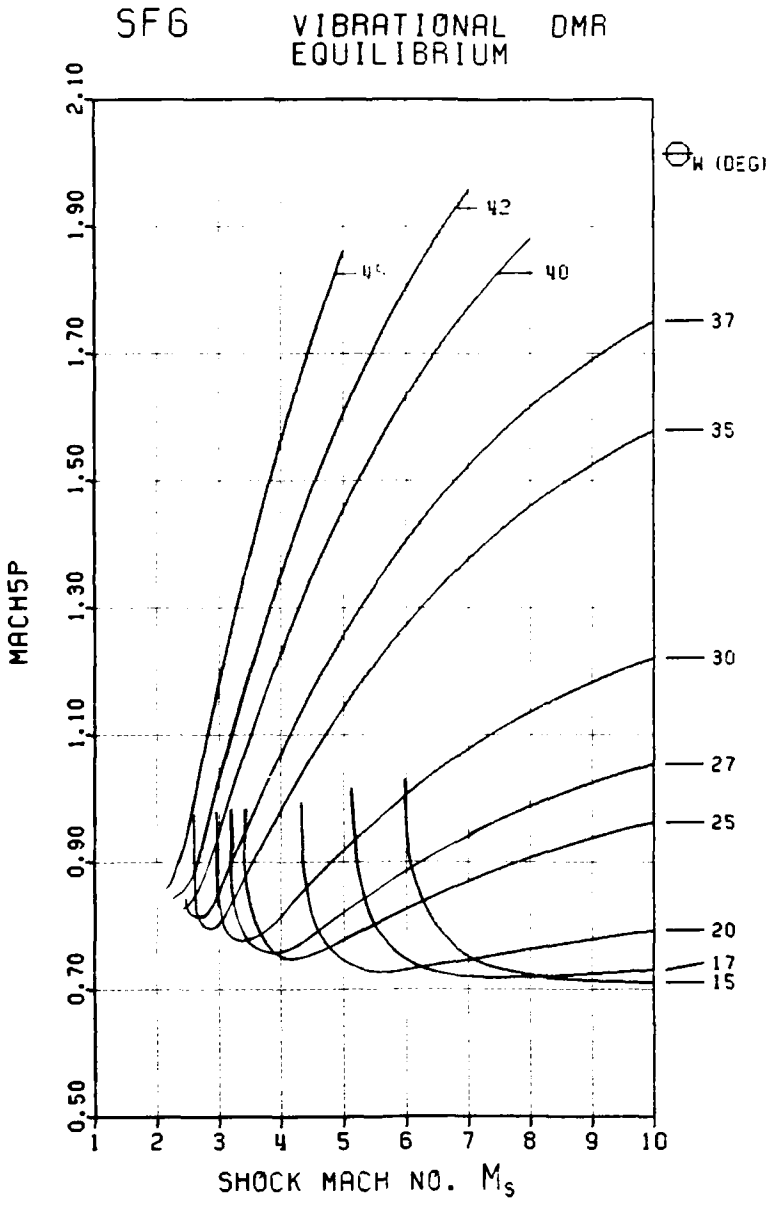

SF6 VIBRATIONAL DMR
EQUILIBRIUM
RHO5/RHOO
0.00
35.00
70.00
105.00
140.00
175.00
210.00
245.00
280.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
45
42
40

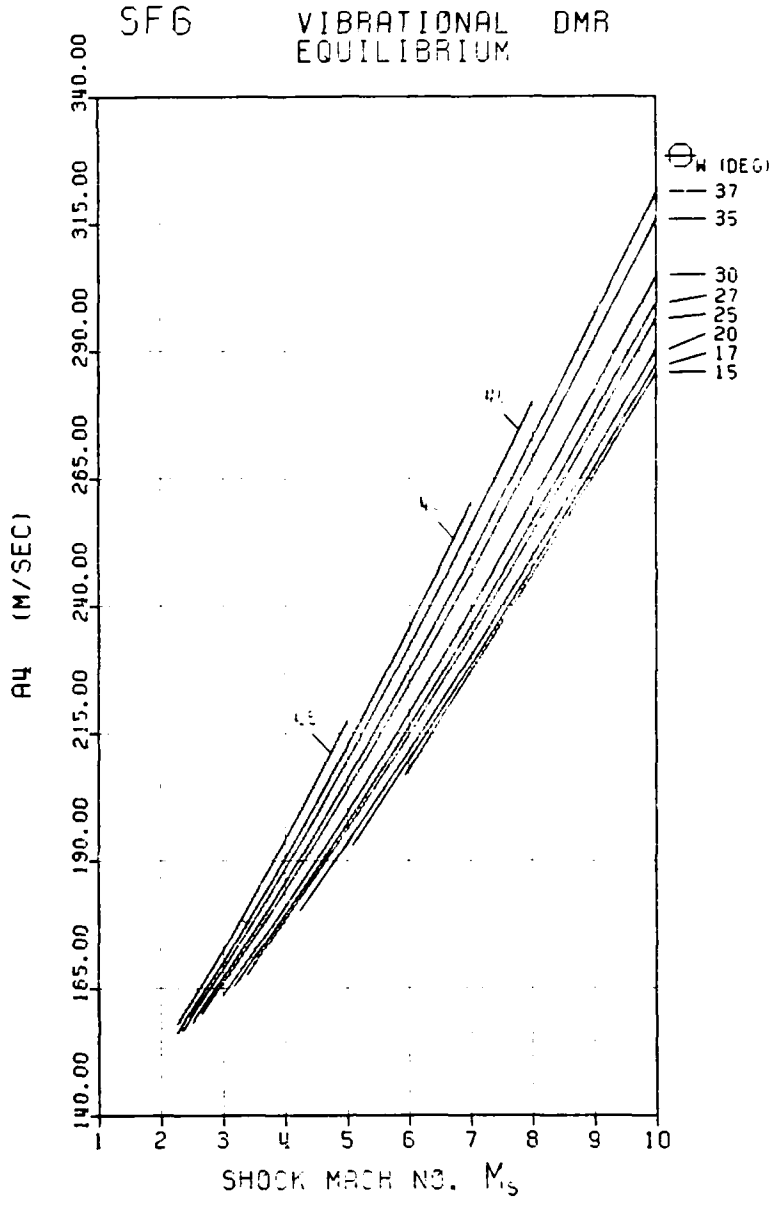

SF6 VIBRATIONAL DMR
EQUILIBRIUM
P4/P0 AND P5/P0
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
45
42
40

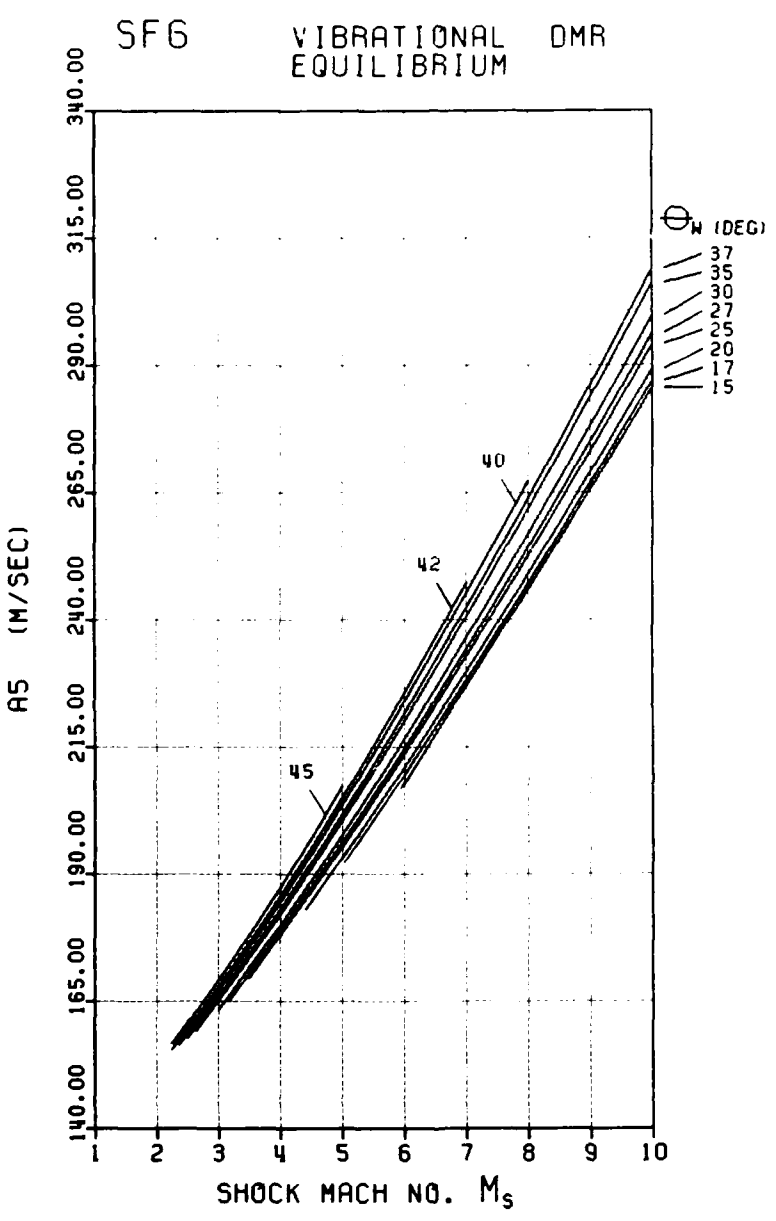

SF6 VIBRATIONAL DMR
EQUILIBRIUM
MACHIP
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
42

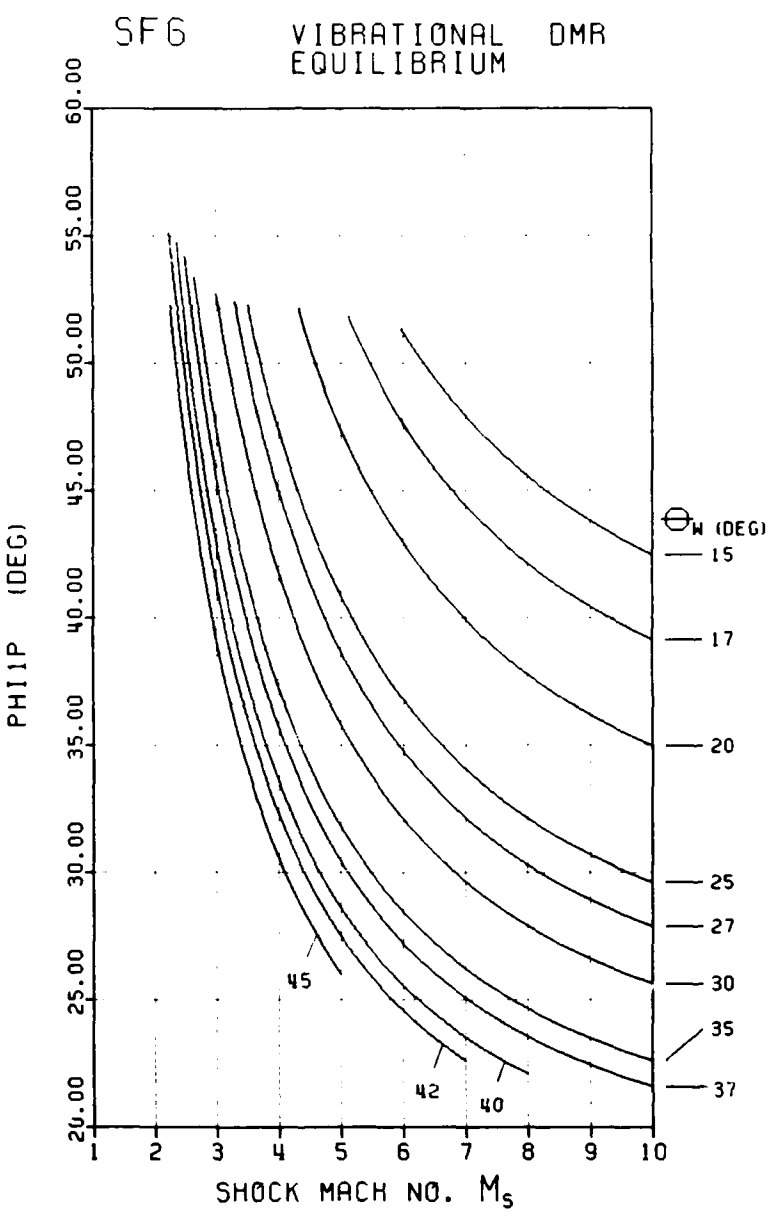

SF6
VIBRATIONAL EQUILIBRIUM
DMR
MACH2P
SHOCK MACH NO. M_S
Θ_W (DEG)
42
40
45
37
35
30
27
25
20
17
15
1,00
1,30
1,60
1,90
2,20
2,50
2,80
3,10
3,40
1
2
3
4
5
6
7
8
9
10

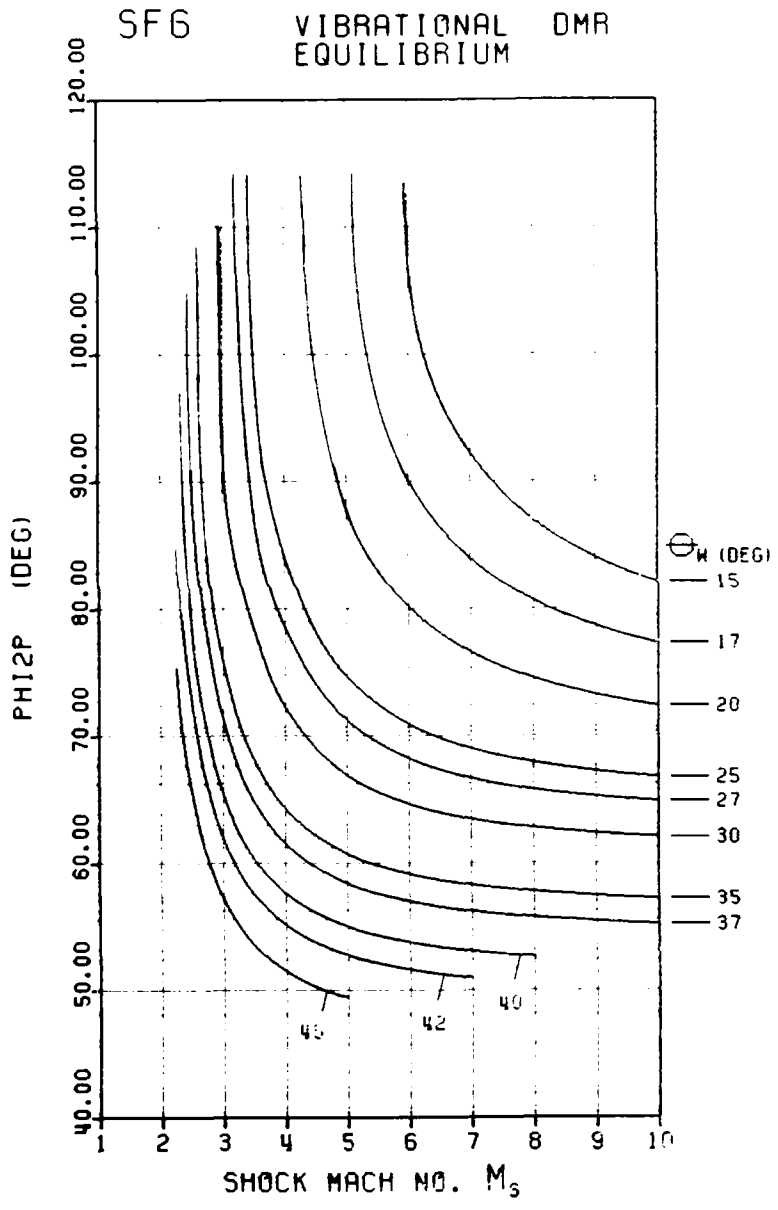

SF6
VIBRATIONAL EQUILIBRIUM
DMR
MACH4P
SHOCK MACH NO. M_S
Θ_W (DEG)
15
17
20
25
27
30
35
37
40
45
42
0,36
0,44
0,52
0,60
0,68
0,76
0,84
0,92
1,00
1
2
3
4
5
6
7
8
9
10

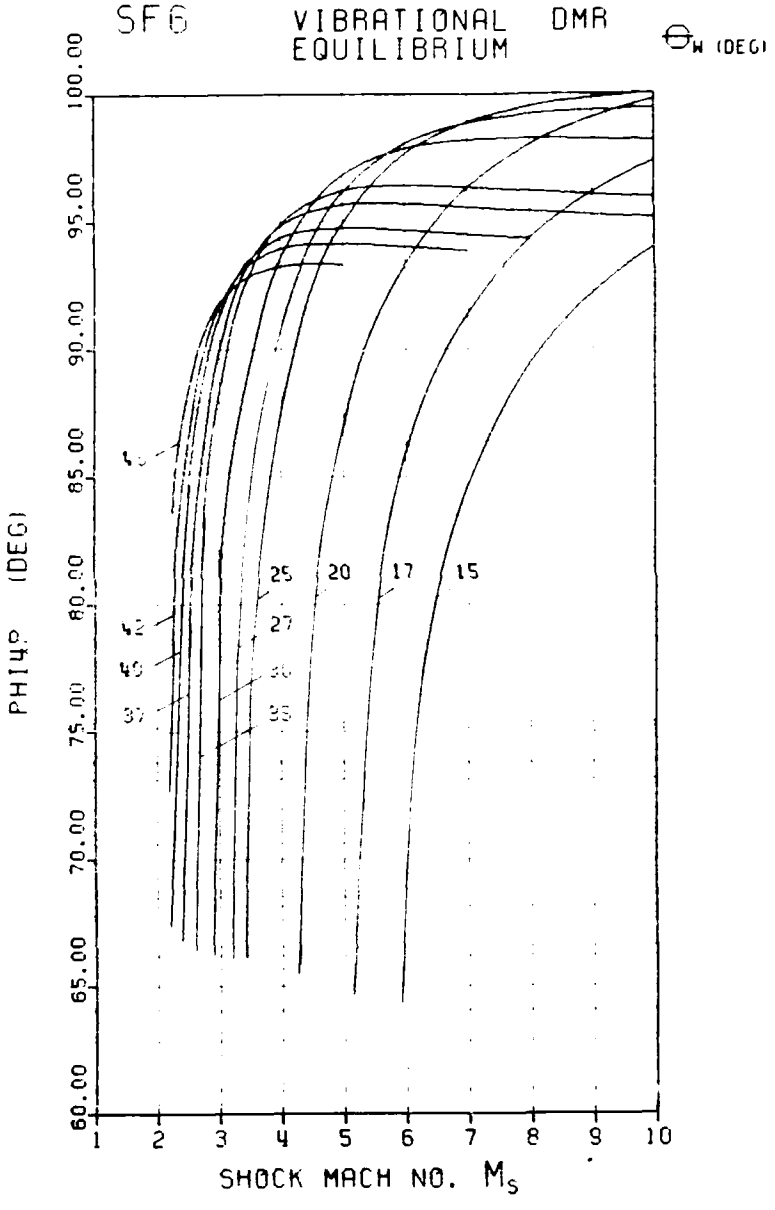

SF6
VIBRATIONAL EQUILIBRIUM
DMR
MACH5P
SHOCK MACH NO. M_S
Θ_W (DEG)
42
40
37
35
30
27
25
20
17
15

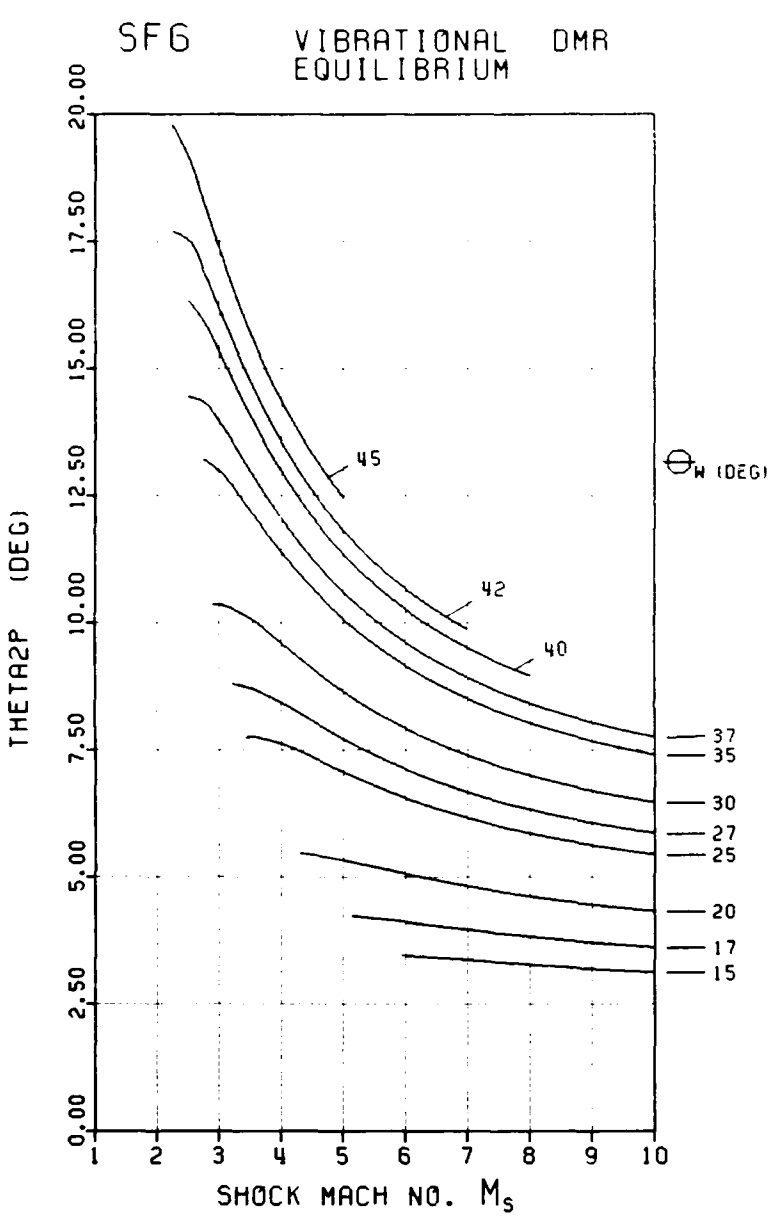

SF6
VIBRATIONAL EQUILIBRIUM
DMR
A4 (M/SEC)
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15

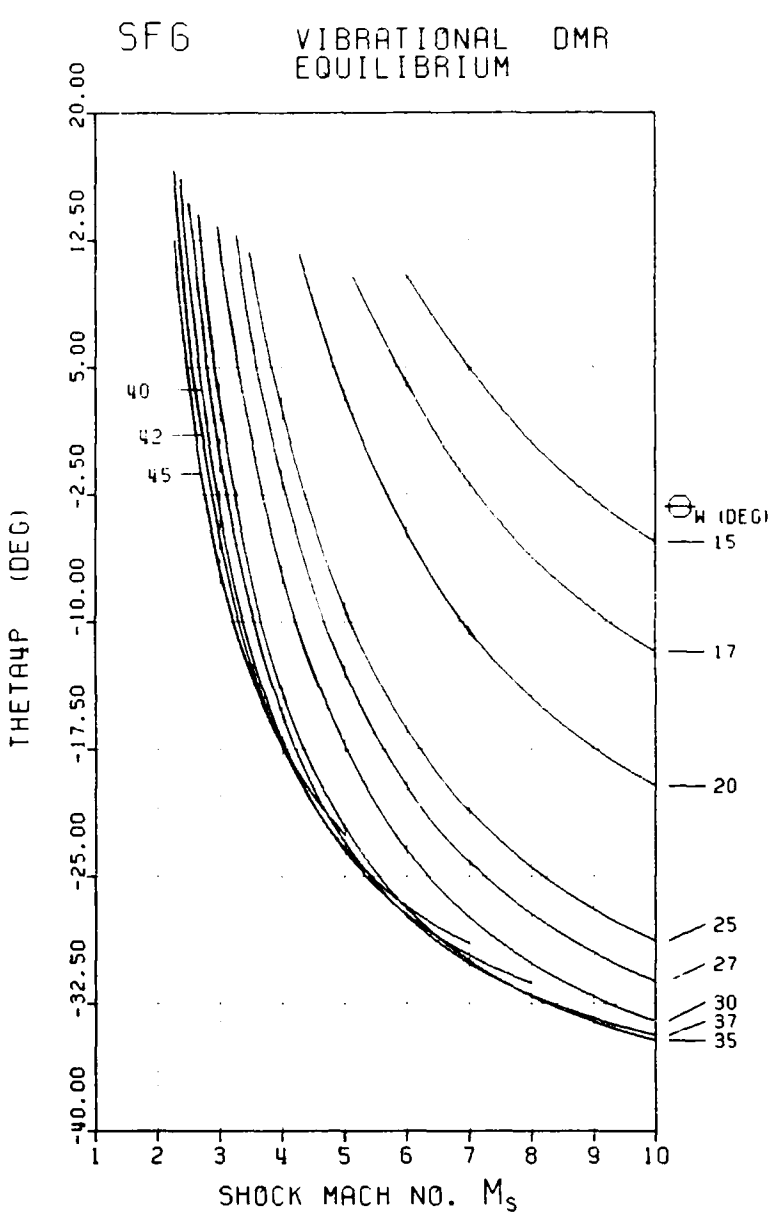

SF6 VIBRATIONAL DMR EQUILIBRIUM
A5 (M/SEC)
340.00
315.00
290.00
265.00
240.00
215.00
190.00
165.00
140.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
40
42
45

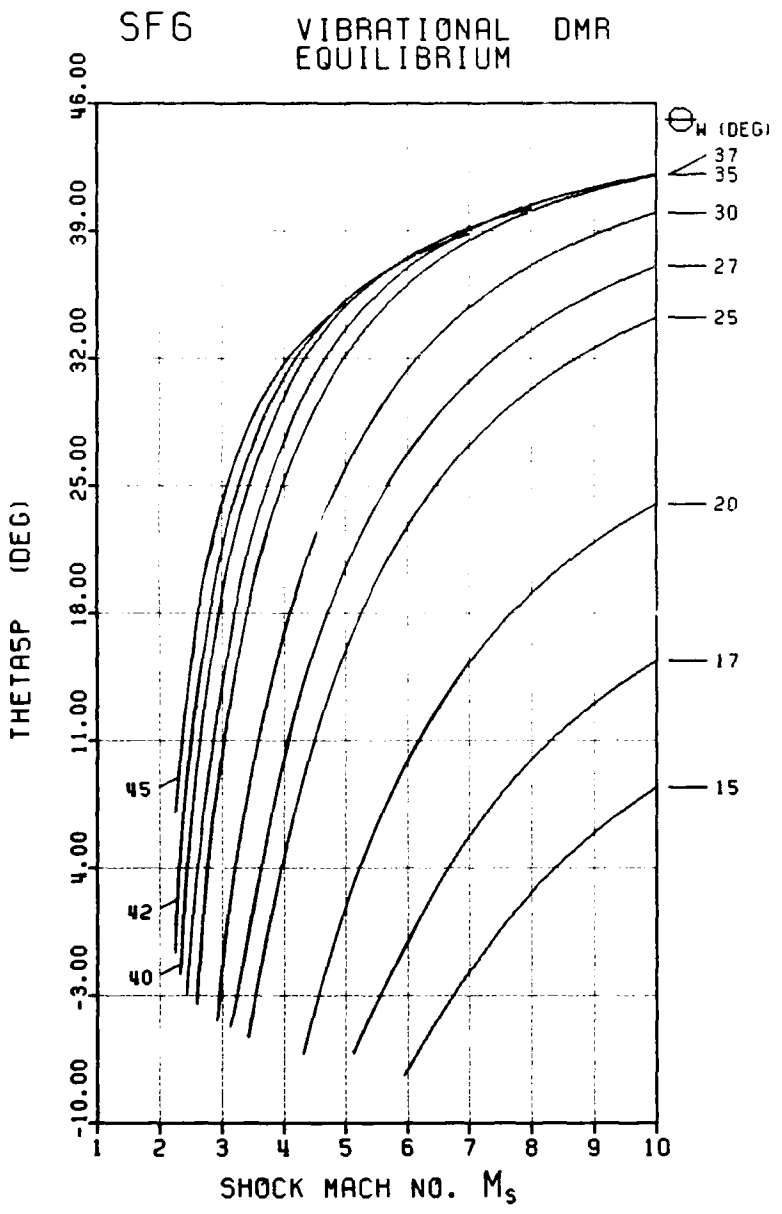

SF6 VIBRATIONAL DMR EQUILIBRIUM
PHI1P (DEG)
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
15
17
20
25
27
30
35
37
45
42
40

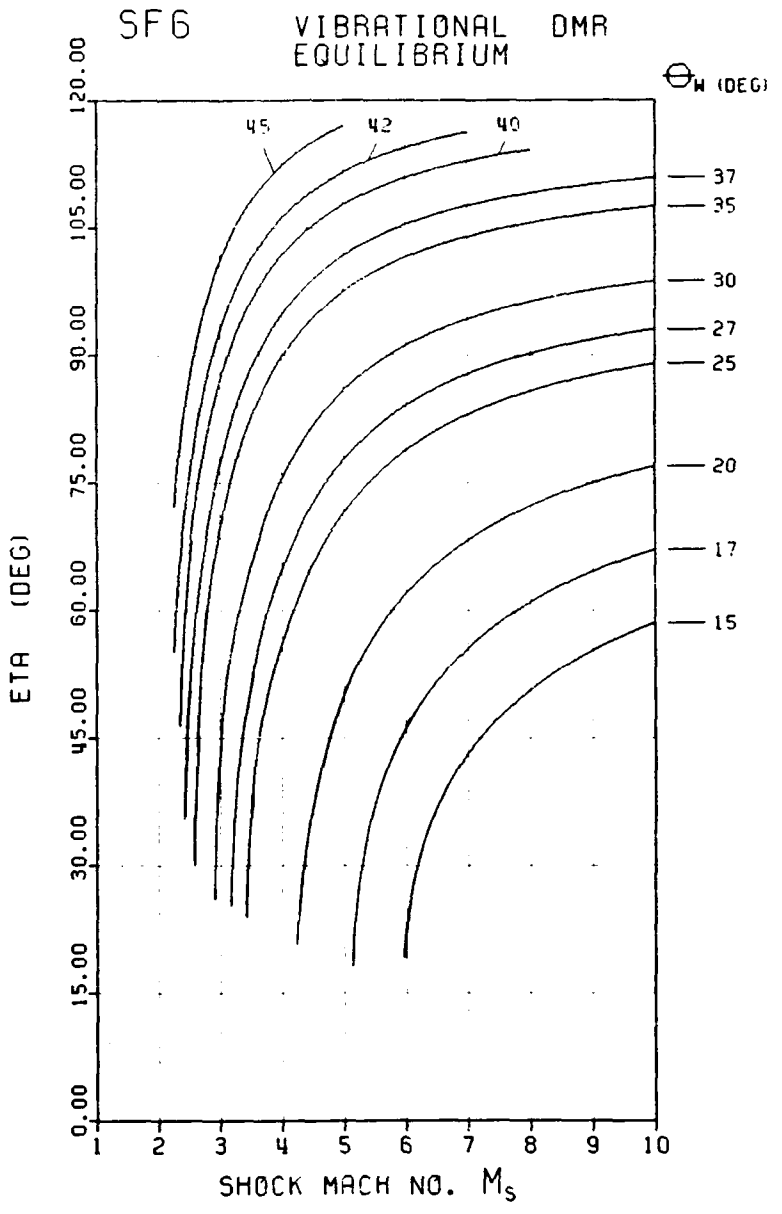

SF6 VIBRATIONAL EQUILIBRIUM DMR
PHI2P (DEG)
SHOCK MACH NO. M_S
Θ_W (DEG)
15
17
20
25
27
30
35
37
40
42
46
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
1
2
3
4
5
6
7
8
9
10

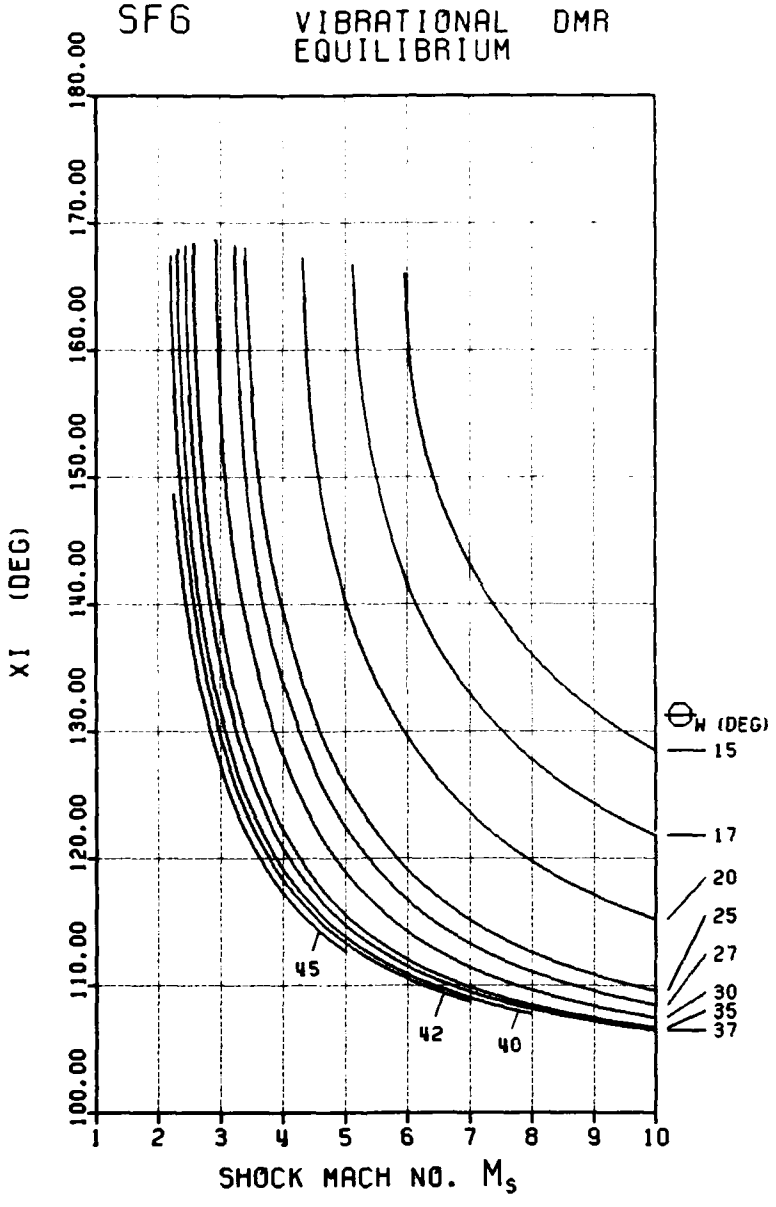

SF6 VIBRATIONAL EQUILIBRIUM DMR
Θ_W (DEG)
PHI4P (DEG)
SHOCK MACH NO. M_S
15
17
20
25
27
42
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
1
2
3
4
5
6
7
8
9
10


SF6 VIBRATIONAL DMR EQUILIBRIUM
THETA2P (DEG)
20.00
17.50
15.00
12.50
10.00
7.50
5.00
2.50
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
30
27
25
20
17
15


SF6 VIBRATIONAL DMR EQUILIBRIUM
THETA4P (DEG)
20.00
12.50
5.00
-2.50
-10.00
-17.50
-25.00
-32.50
-40.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
40
42
45
15
17
20
25
27
30
37
35


SF6 VIBRATIONAL DMR EQUILIBRIUM
THETASP (DEG)
46.00
39.00
32.00
25.00
18.00
11.00
4.00
-3.00
-10.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
37
35
30
27
25
20
17
15
45
42
40


SF6 VIBRATIONAL DMR EQUILIBRIUM
ETA (DEG)
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
1 2 3 4 5 6 7 8 9 10
SHOCK MACH NO. M_S
Θ_W (DEG)
45
42
40
37
35
30
27
25
20
17
15


SF6
VIBRATIONAL EQUILIBRIUM
DMR
XI (DEG)
180.00
170.00
160.00
150.00
140.00
130.00
120.00
110.00
100.00
1
2
3
4
5
6
7
8
9
10
SHOCK MACH NO. M_S
Θ_W (DEG)
15
17
20
25
27
30
35
37
45
42
40

APPENDIX A

ACTUAL SIDEWALL PRESSURE HISTORY AND NUMERICAL RESULTS

Recently, Deschambault (Ref. 11) measured the pressure history on and above a 40° wedge for the four types of pseudo-stationary oblique-shock-wave reflection in air. The numerical results generated by the present work are compared with the experimental pressure histories recorded by Deschambault and the results from the numerical simulation done by Glaz (Ref. 12) for a case of DMR in air. The comparison is applied only to the regions around the two triple points due to the limitations of the three-shock theory. Hence, only the sidewall pressure histories are considered. The wedge surface and sidewall pressure histories can be found in Ref. 11. Figure A-1 illustates the sidewall pressure gauge positions used in the experiments by Deschambault.

Initial conditions : $M_s = 3.72$, $\theta_w = 40°$, $P_0 = 45$ torr (6 kPa) and $T_0 = 21.94°C$

The infinite-fringe interferogram is presented in Fig. A-2. Since the flow is self-similar, the position of the gauge "path" across the wave system can be traced by superimposing Fig. A-1 onto Fig. A-2. The traced positions of the gauges in the reflection system are shown schematically in Fig. A-3. In this run, both gauges 6 and 7 were below the first triple-point trajectory. Gauge 6 measured the pressure jumps across the Mach stem M from state (0) to state (3) close to the wedge surface, across the rolled up slipstream and across the tip of the second Mach stem M' to state (5). Gauge 7 is located slightly above gauge 6 and it recorded the pressure across the primary Mach stem M, across the upper portion of the rolled up slipstream S and across the second Mach stem M' from state (2) to state (5). Gauge 8 was located above the first triple-point trajectory but below the second triple-point trajectory. Gauge 8 was able to measure the pressure jumps across the incident shock wave I to state (1), across the primary reflected shock wave R to state (2), and across the second triple point T' to state (5). Gauge 9 was positioned above the first and second triple-point trajectories. It recorded the pressure jumps across the incident shock wave I to state (1) and across the second reflected shock wave R' to state (4) just behind the second triple point T'. The experimental sidewall pressure histories are shown in Fig. A-4. The measured pressures of the various flow states are indicated in Fig. A-4 and the various states in Fig. A-7.

The corresponding pressure histories at the four gauge locations given by the numerical simulation of Glaz (Ref. 12) are presented in Fig. A-5. Since each station is merely a mesh point on the numerical grid network, the time resolution of the numerical simulation is much greater than that of the pressure gauge. In addition, the numerical records have infinite rise times, whereas physically the gauge has a finite dimension and rise times limited to about 4 μs. The pressure histories generated by the numerical code trace the local and instantaneous pressure variations ideally at a point station. Experimentally, a pressure gauge provides the average pressure over its finite recording area and the peak signals are

smoothed out because of the limited transient response time. The pressure jump across each shock wave is indicated in torr and kPa units on the plots. The lower pressure experienced at station 6 than at station 7 across the rolled up slipstream is clearly shown in Fig. A-5 by the sharp dip immediately behind the jump across the primary Mach stem M at station 6 here. The pressure jumps recorded by gauge 8 across the incident shock, first reflected shock and the second Mach stem are not as sharp and definite as shown by the simulated results. In the measured pressure history, the rise from P_2 to P_5 are continuous. However the simulation has a pressure peak at P_2, then the pressure dips slightly before rising up to P_5. Gauge 8 and 9 both measured about the same P_1, but gauge 9 has a longer record of P_1 than gauge 8 because gauge 9 went from state (1) to state (4) above T', whereas gauge 8 went from state (1) through state (2) to state (5) below T'. Due to the limited time record of the simulated pressure history given at station 9, the shape of the pressure history and the value of P_4 cannot be read and compared with the measured value. However P_4 can be read out from the isobaric contours of the entire reflection configuration (Fig. A-6).

The isobaric contours of the entire flow field (Ref. 12) and the enlargement of the flow regions around the two triple points are presented in Fig. A-6. From Fig. A-6(b), both P_2 and P_3 behind the first triple point are 2×10^6 dynes/cm^2 or 200 kPa (1500 torr), and both P_4 and P_5 behind the second triple point are 3×10^6 dynes/cm^2 or 300 kPa (2250 torr). Besides extracting the pressure information from the isobaric contour plots, several reflection angles can also be measured from this figure for comparing with the experimental values. The angles of interest are: (1) angle between incident shock wave and reflected shock wave at the first triple point δ, (2) angle between first reflected and second reflected shock η, (3) angle between first reflected shock and second Mach stem ξ, (4) first triple-point trajectory angle χ, and (5) second triple-point trajectory angle χ'. Refer to Fig. A-7 for the definition of these angles.

The computer program that calculates the various thermodynamic states was modified so that a unique thermodynamic of state could be specified for each flow region. This is seen to be important for doing analysis in air where several flow regions may still be frozen while the rest of the flow regions may be in equilibrium. Concerning equilibrium flow in air, there may be some circumstances where only the oxygen molecules are in vibrational equilibrium, or in some other cases, both oxygen and nitrogen molecules are in vibrational equilibrium. Since the incident shock Mach number is low in this case, no dissociation needs to be included in the analysis. To determine whether the flow is frozen or in equilibrium, relaxation length concepts are used. If the relaxation length of an internal degree of freedom is considerably shorter than a characteristic length, the state is considered to be in equilibrium. Otherwise, it is assumed to be frozen. The vibrational relaxation length of N_2 is calculated according to the data reported by White and Millikan (Ref. 13) which shows that below a temperature of 3000 K at a pressure of one atmosphere, N_2 is excited more rapidly in air than in pure N_2. The vibrational relaxation length of O_2 in air is calculated using the relation given by Lutz and Kiefer (Ref. 14) for pure O_2. Also included is the correction factor introduced by Vincenti (Ref. 15). This takes into

account the experimental findings of Blackman (Ref. 16) that O_2-N_2 collisions in air are only 40% as effective as O_2-O_2 collisions in transferring energy for vibrational readjustment of O_2. According to this analytical model, states (0), (1) and (2) are frozen, whereas the flow in states (3), (4) and (5) are in O_2 vibrational equilibrium. The vibrational relaxation length calculated by the present program is 38 mm in state (1), 16 mm in state (2), 3 mm in state (3), 7 mm in state (4) and 9 mm in state (5). Results of this model are listed in Table A-1 under present analysis (A).

Glaz used in his simulation the real-gas equation of state for air by Deschambault (Ref. 17), which was originally developed by Hansen (Ref. 18). Glaz's results indicated that all flow regions of the reflection system should be in equilibrium and a frozen gas assumption would not be valid. Another run was done using the present program based on the assumption that all five flow regions are in vibrational equilibrium and the results are listed in Table A-1 under present analysis (B). The pressure of each flow region and the reflection angles measured or calculated from experiment, numerical simulation and analysis are all tabulated in Table A-1. Both the numerical simulation (Ref. 12) and the analysis from the present work give extremely good results for pressures in the flow regions (1) to (3) with a maximum discrepancy of 2.5%. The measured P_3 of gauge 7 was used for comparison since gauge 6 gave a lower value because the vortical flow of the rolled up primary slipstream went past gauge 6. Behind the second triple point T', the pressures P_4 and P_5 given by Glaz are consistently higher than the measured values by 13.6% and 10.5%, respectively. However, the numerical results from the present study gave similar results to the experimental P_4 and P_5 values with the maximum deviation only 3.6% for set (A) and 7.1% for set (B).

The pressures predicted by the present analysis (A) agree very well with the measured pressures from the experiment. However, the pressures predicted by the present analysis (B) agree better with the numerical simulation results than with the measurements from experiment.

The first triple-point-trajectory angle χ was predicted very well by Glaz and the present work with a maximum deviation of 0.5°. The second triple-point-trajectory angle χ' was very well predicted by the present analysis (A). Numerical simulation and present analysis (B) give slightly smaller values of χ' than the measured experimental value. The present analyses (A) and (B) give values of the reflection angles δ, ξ and η to within 1.6° and 3.5° respectively that of the experimental value for this case. Glaz predicted the angles δ and η being 4° and 3.5° respectively too high, whereas the angle ξ had a value of 9.5° too low. Present analysis (A) agrees best with experiment on physical quantities. Present analysis (B) give very reasonable physical angles except the value of χ' is slightly low. Numerical simulation predicts triple point trajectory angles well but not so for the reflection angles.

A comparison of the values of δ shows how well the numerical work from the present study can predict the orientation of the reflected shock wave R at the first triple point T relative to the incident shock wave I. Similarly, comparisons of the angle ξ and η indicates the accuracy of the numerical work in predicting the orientation of the second reflected shock

wave R' and the second Mach stem M' relative to the primary reflected shock wave R. The numerical simulation by Glaz predicts a smaller angle ξ and a larger angle η than the experimental and analytical values, and it gives larger values of P_4 and P_5. This is because decreasing ξ will place the second reflected shock R' more normal to the incoming flow, subsequently increasing the pressure P_4 behind it in region (4). Similarly, as the second Mach stem M' becomes stronger, the angle η gets larger and the incoming flow in region (2) is now more normal to the second Mach stem M', thus resulting in a higher pressure P_5 in region (5).

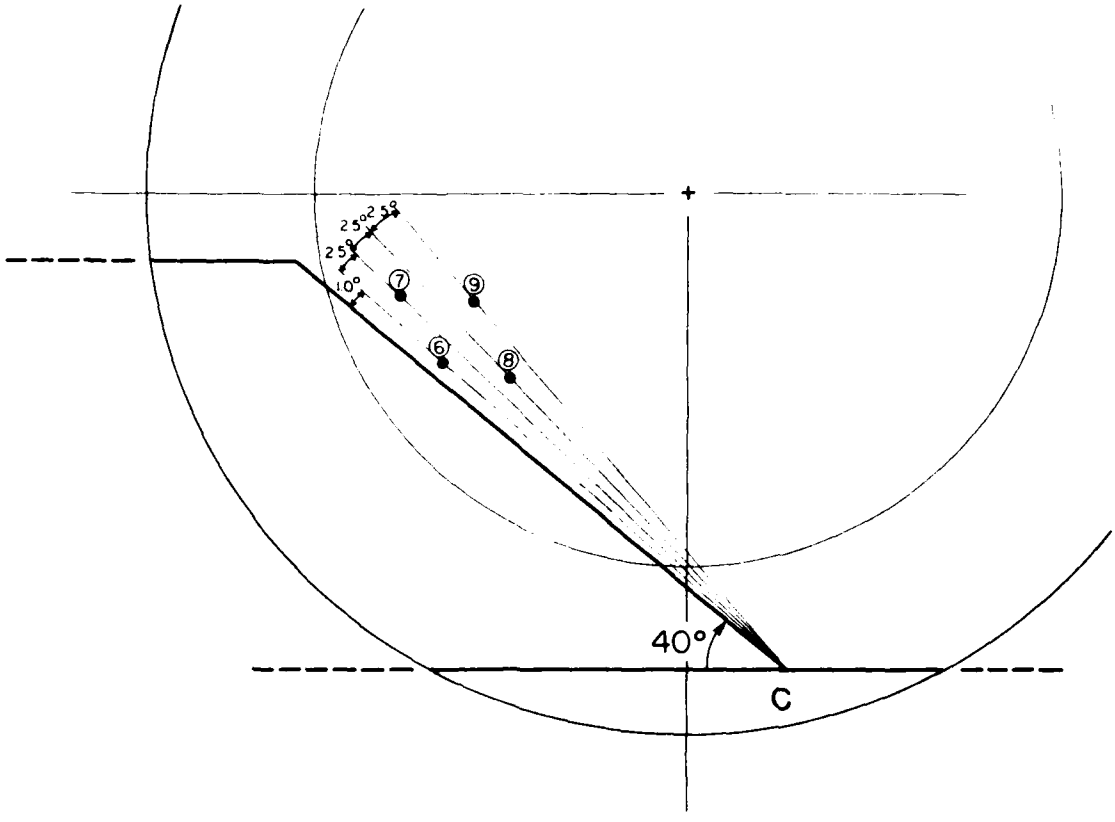
Present analysis (A) has given results for the pressure at all five states (1) to (5) showing good agreement with experiment. It can predict accurately the orientations of the shock waves around the two triple points. The good agreement indicates that the application of different equations of state to each region is justified based on relaxation length concepts. The numerical simulation by Glaz provides more detailed information about the entire flow field in contrast to the present work. However, his results show larger deviations in the pressures behind the second triple point and in the reflection angles when compared to the experimental results.

TABLE A-1

Comparison of Pressures and Physical Angles between Experiment and Numerical Results for a DMR in Air.

$M_s = 3.72$, $\theta_w = 40°$, $P_0 = 45$ torr (6 kPa), $T_0 = 21.94°C$.

Parameter	Experiment (Ref. 11)			Numerical Simulation (Ref. 12)			Present Analysis (A)		(B)	
	Torr	kPa	Gauge	Torr	kPa	Station	Torr	kPa	Torr	kPa
P_1	716	95.5	8	728	97.1	8	719	95.9	730	97.3
	722	96.3	9	728	97.1	9				
P_2	1456	194.1	8	1455	194.0	8	1439	191.9	1449	193.2
P_3	1476	196.8	7	1506	200.8	7	1439	191.9	1449	193.2
	1396	186.1	6	1542	205.6	6				
P_4	1981	264.1	9	2250	300.0	Fig.A-5	2052	273.6	2122	282.9
P_5	2045	272.6	8	2259	301.2	8	2052	273.6	2122	282.9
χ	5.0°			5.5°			4.8°		4.5°	
χ'	7.8°			7.0°			7.4°		6.5°	
δ	123.0°			127.0°			124.0°		126.2°	
ξ	162.5°			153.0°			160.9°		159.0°	
η	46.5°			50.0°			45.4°		47.7°	



Gauge 6 is 8.56 cm from C

Gauge 7 is 9.65 cm from C

Gauge 8 is 7.75 cm from C

Gauge 9 is 8.76 cm from C

Fig. A-1 Schematic diagram of gauge positions on the specially constructed steel window.

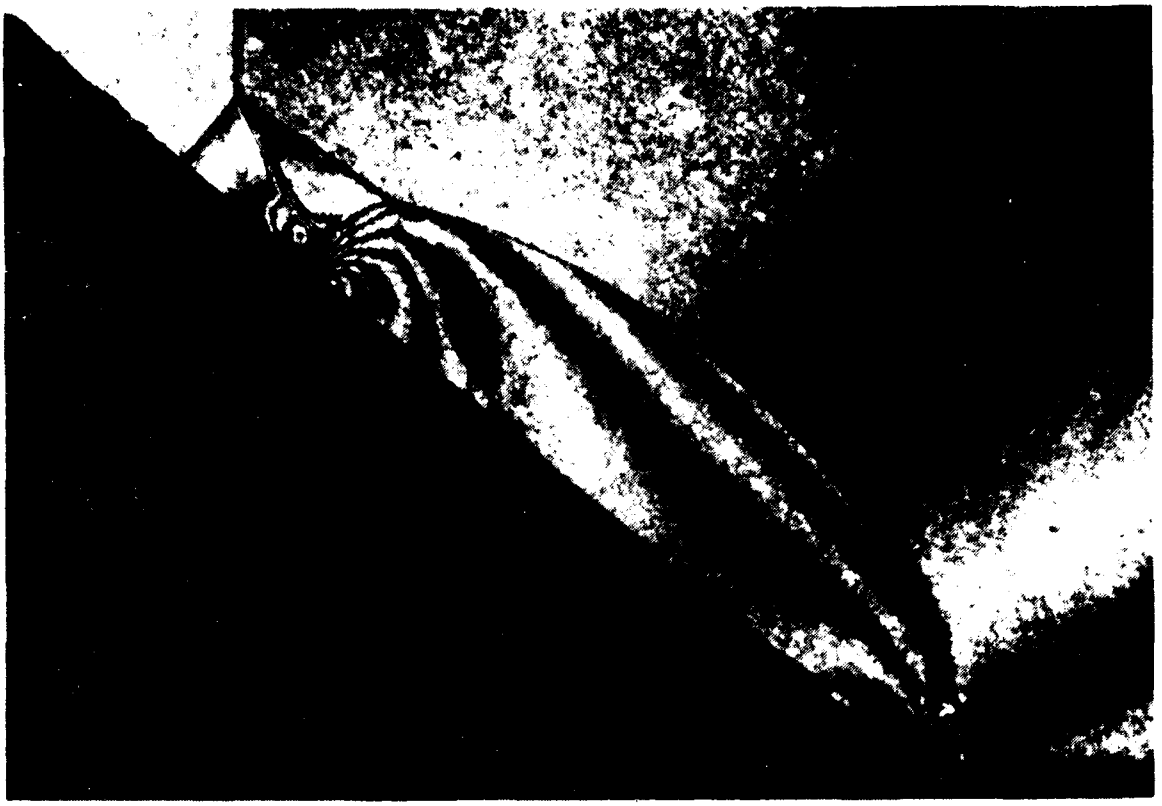


Fig. A-2 Infinite-fringe interferogram of double-Mach reflection in air (Ref. 11). M_S = 3.72, θ_w = 40°, P_0 = 45 torr (6 kPa), T_0 = 21.94 °C and λ = 6943 Å.

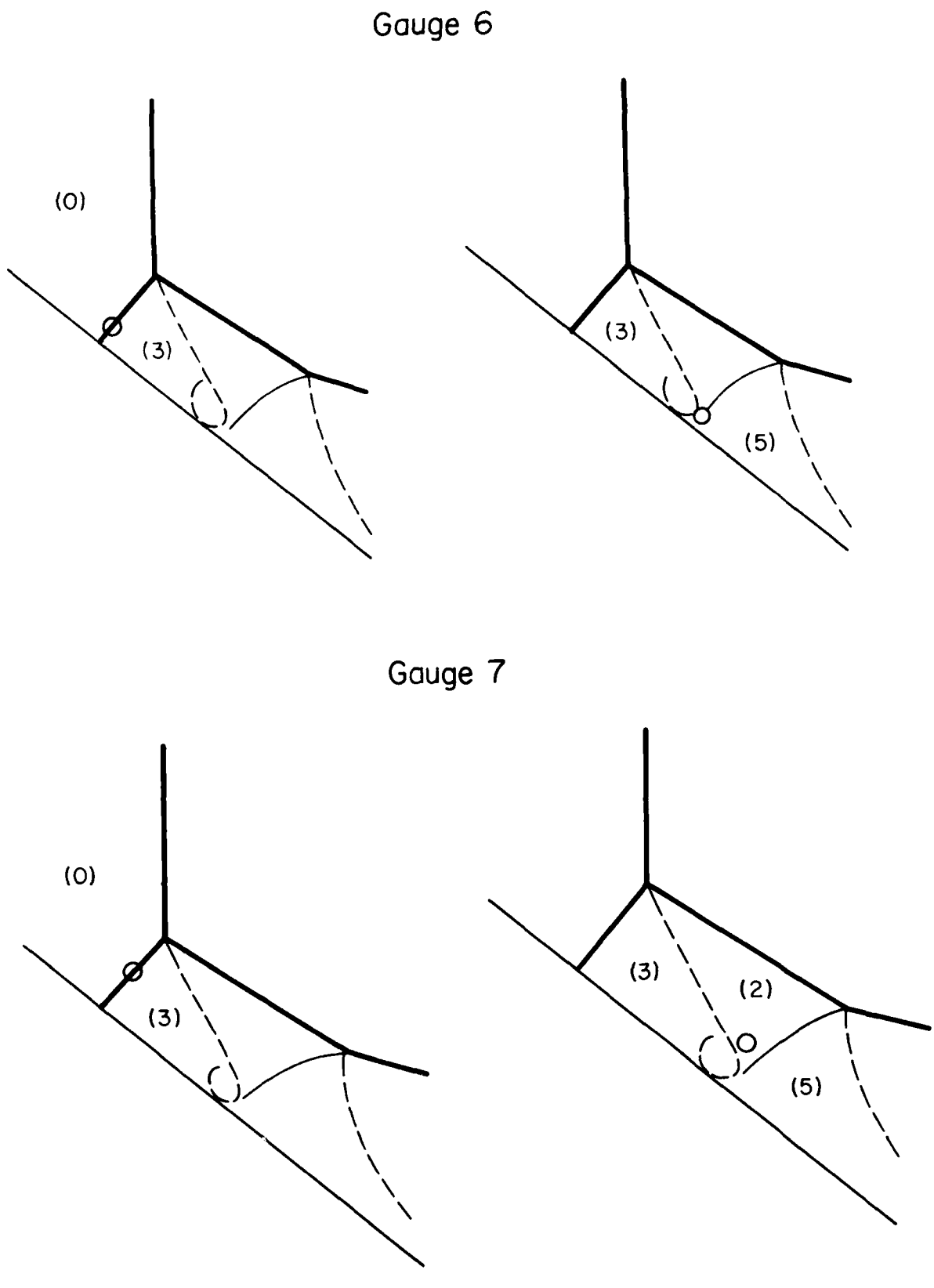
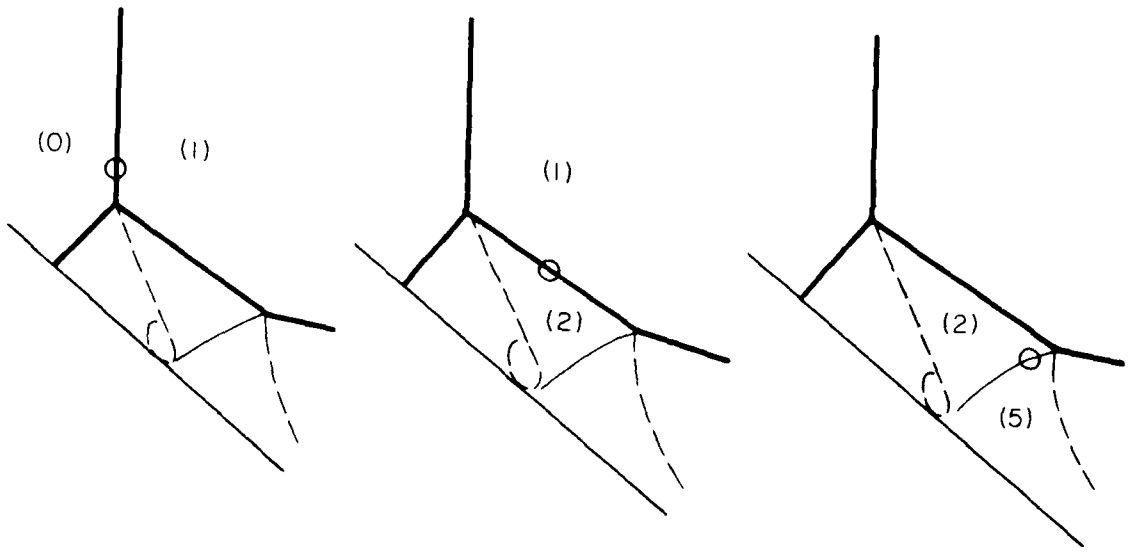


Fig. A-3 Positions of the gauge path across the reflection system traced by superimposition.

Gauge 8



Gauge 9

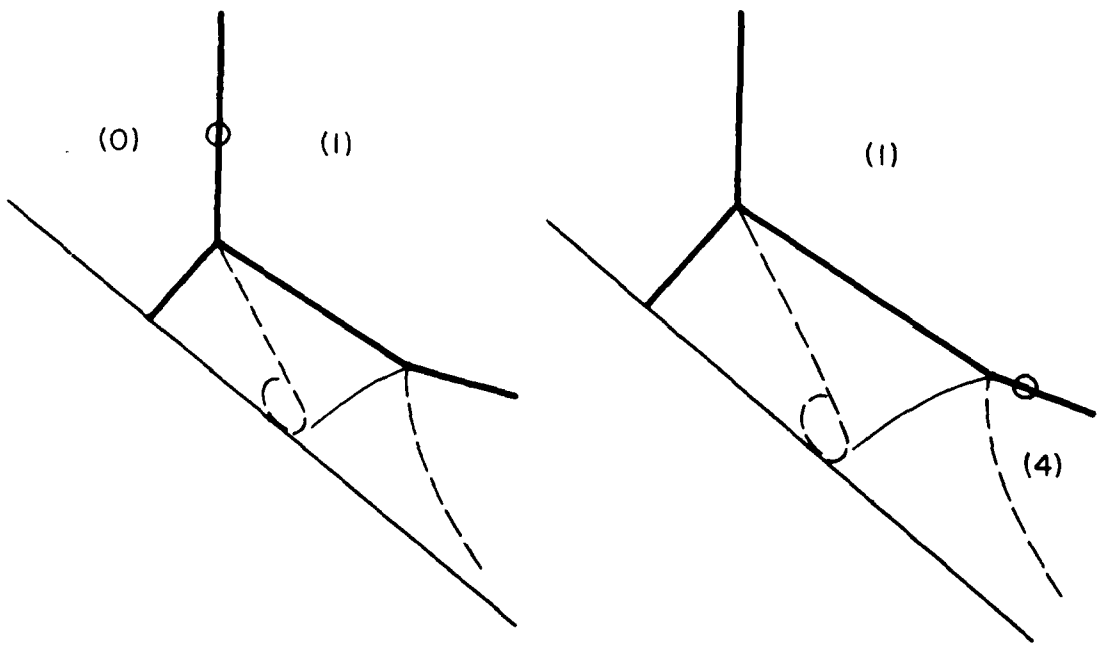
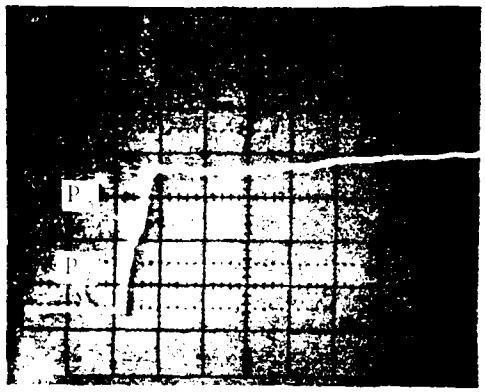


Fig. A-3 (Continued) Positions of gauge path across the reflection system by superimposition.

GAUGE 6



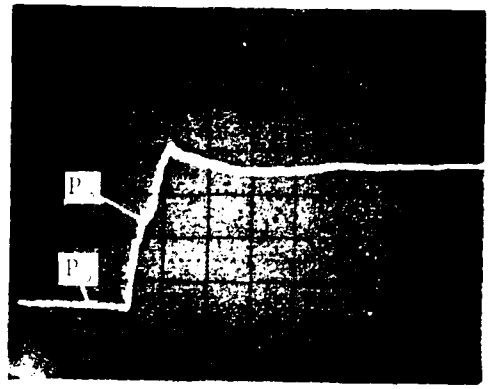
90.80 kPA/div (vertical)

20 s/div (horizantal)

P_0 45 torr (6 kPa)

P_3 1396 torr (186.1kPa)

GAUGE 7



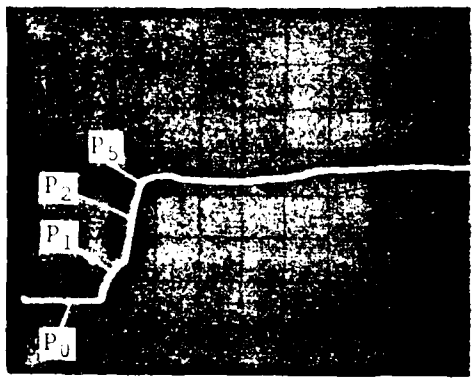
95.42 kPa/div (vertical)

20 s/div (horizantal)

P_0 45 torr (6 kPa)

P_3 1476 torr (196.8 kPa)

GAUGE 8



98.80 kPa/div (vertical)

20 s/div (horizontal)

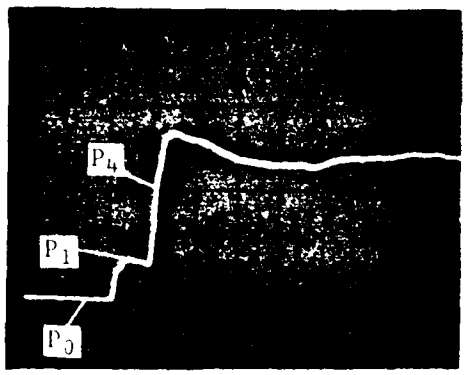
P_0 45 torr (6 kPa)

P_1 716 torr (95 55 kPa)

P_2 1456 torr (194.1 kPa)

P_5 2045 torr (272.6 kPa)

GAUGE 9



98.18 kPa/div (vertical)

20 s/div (horizontal)

P_0 45 torr (6 kPa)

P_1 722 torr (96.3 kPa)

P_4 1981 torr (264 1 kPa)

Fig. A-4 Pressure history measurements along the sidewall above the wedge surface for the case of double-Mach reflection in air by Deschambault (Ref. 11). M_S = 3.72, θ_w = 30°, P_0 = 45 torr (6 kPa), T_0 = 21.94 °C.

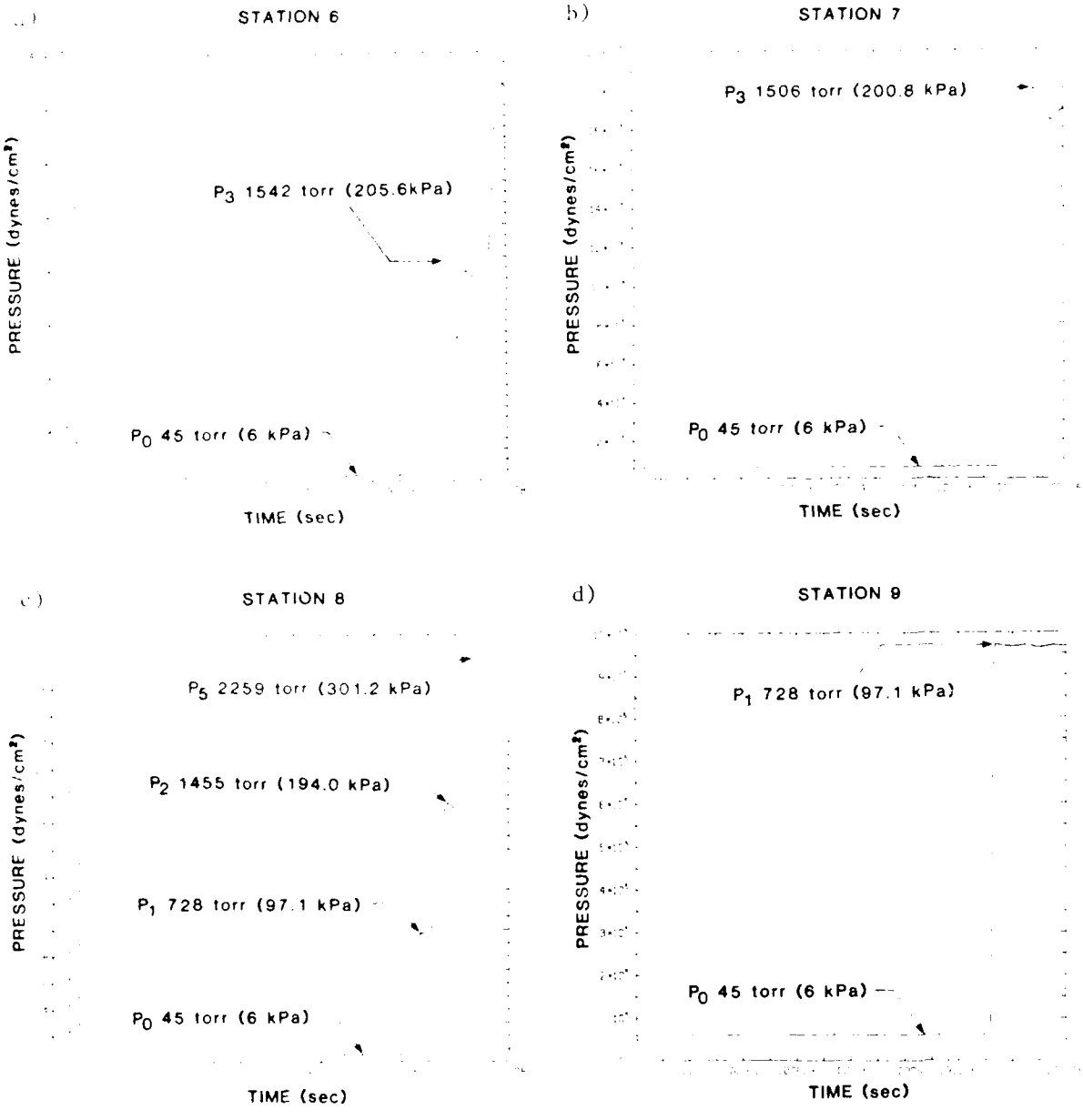
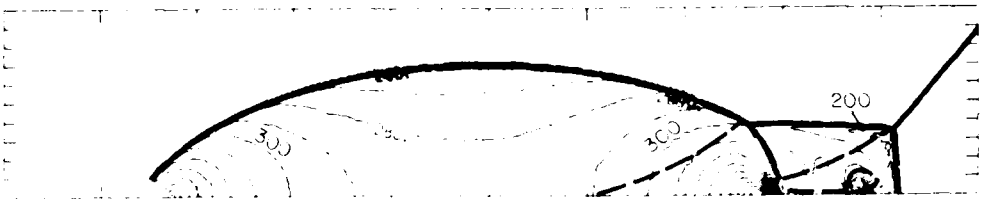


Fig. A-5 Numerical simulation of pressure history by Glaz (Ref. 12). for the case of double-Mach reflection in air. M_s = 3.72, θ_w = 40°, P_0 = 45 torr (6 kPa), T_0 = 21.94 °C.

a) Isobaric contours of the entire flow field



b) Isobaric contours of the flow regions around the two triple points

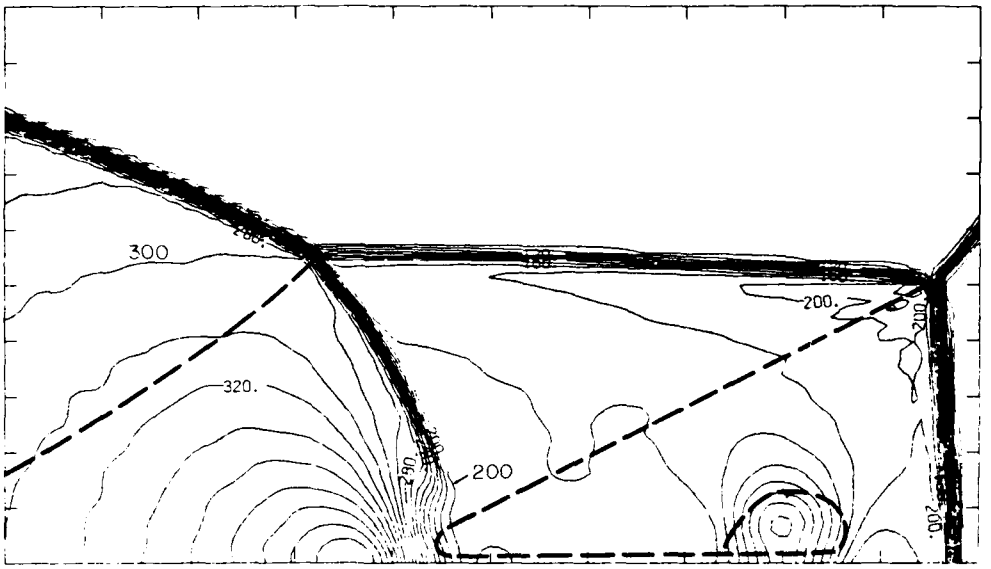


Fig. A-6 Numerical simulation of pressure contours by Glaz (Ref. 12) for the case of double-Mach reflection in air. M_s = 3.72, θ_w = 40°, P_0 = 45 torr (6 kPa), T_0 = 21.94 °C and γ = 1.4. Contours are shown from 0.0 to 3.8 x 10^6 dynes/cm^2 with an interval of 1.0 x 10^5 and labels are scaled by 1.0 x 10^{-4}.

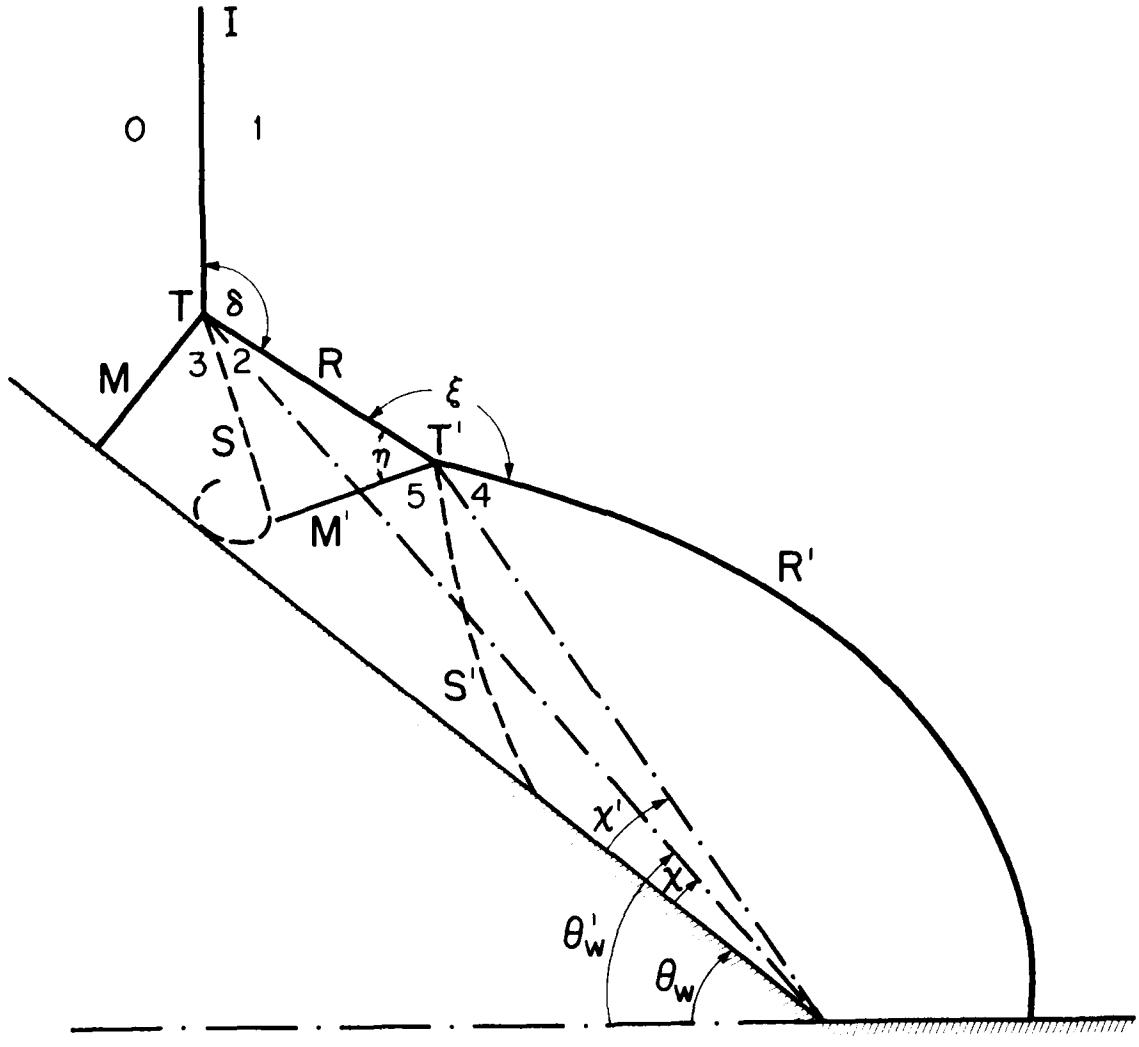


Fig. A-7 Schematic diagram of double-Mach reflection.

APPENDIX B

COMPUTER-PROGRAM LISTING FOR THE ANALYTICAL SOLUTION OF REGULAR AND MACH REFLECTIONS

The computer program listed here follows the method of calculation discussed in Section 2. The program is very general and is used for argon, nitrogen, air, carbon dioxide and sulfur hexafluoride. It allows a choice of frozen, perfect or vibrational equilibrium thermodynamic states. It can be easily modified to include any other gas by changing SUBROUTINE GAS.

The program will first check whether the input flow conditions can give regular reflection by calling SUBROUTINE RR. If it fails to obtain a solution, the program will proceed to call SUBROUTINE SIMMR to calculate Mach reflection case. If the actual wedge angle has been chosen as the parameter, the program will predict a trajectory angle for the first triple point. However, if the effective wedge angle has been chosen as the parameter, the program will iterate the wedge angle until the calculated effective wedge angle is the same as the input one. After solving for the first triple-point system, a check of the flow Mach number in region (2) with respect to the kink is done. If that is a supersonic flow, the second triple-point system will be solved by calling SUBROUTINE TRPL2. The subroutines are listed following the main program alphabetically. Input data are explained in the main program. The program is run on the Perkin Elmer 3250 Computer System at UTIAS.

```
C  ************************************************************
C  ******                                                ******
C  ******   COMPUTER-PROGRAM LISTING FOR THE ANALYTICAL   ******
C  ******   SOLUTION OF REGULAR AND MACH REFLECTIONS      ******
C  ******                                                ******
C  ******   UNIVERSITY OF TORONTO                        ******
C  ******   INSTITUTE FOR AEROSPACE STUDIES              ******
C  ******                                                ******
C  ******   WRITTEN BY:  Masao Shirouzu (November 1981)  ******
C  ******   REVISED BY:  Tin Cheung J. Hu (January 1983) ******
C  ******                                                ******
C  ************************************************************


C  ------------------------------------------------------------
C  ------------------------------------------------------------
C                  MAIN PROGRAM
C  ------------------------------------------------------------
C  ------------------------------------------------------------


      REAL MACHS,MACH0,MACH1,MACH2
      DOUBLE PRECISION G0,ALPHA,BETA,DP0,DP1,DP2,DT0,DT1,DT2,DRHO0,DRHO1
     1,DRHO2,DA0,DA1,DA2,DUM,DPR,DTM,AS
      DIMENSION MA(2),PR(2),TM(2),PH(2),TH(2),IST(2),VRL(2)
      COMMON IREAL,IGAS,G0,ALPHA,BETA,IP,IQ
      COMMON /ST/ISTAT0,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5
      COMMON /GUESS/GT2,GT4
C
C     ..................................................................
C
C     INPUT DATA :
C        IGAS       TYPE OF GAS (SEE SUBROUTINE GAS)
C        IREAL      EQUATION OF STATE (SEE SUBROUTINE GAS)
C        IP         CHOICES OF ASSIGNING EQUATION OF STATE
C                      1 - ASSIGNED BY PROGRAMMER,
C                      2 - ASSIGNED BY THE PROGRAM BASED ON VIBRATIONAL
C                          RELAXATION LENGTH
C        IQ         CHOICES OF PARAMETER
C                      1 - THETA WALL,
C                      2 - THETA WALL PRIME
C        GT2,GT4    INITIAL GUESSES FOR PHI2P AND PHI4P (DEG.)
C        IST(0-5)   EQUATION OF STATE FOR FLOW REGIONS (0) TO (5)
C        NUM        EXPERIMENT NUMBER
C        MACHS      INCIDENT SHOCK MACH NUMBER
C        PRS0T      INITIAL PRESSURE (TORR)
C        TMP0       INITIAL TEMPERATURE (DEG. CELSIUS)
C        PTHW       WEDGE ANGLE THETA WALL (DEG.)
C        CHI        FIRST TRIPLE-POINT-TRAJECTORY ANGLE (DEG.)
C     ..................................................................

      READ(5,501) IGAS,IREAL,IP,IQ,GT2,GT4
      READ(5,506)IST0,IST1,IST2,IST3,IST4,IST5
1     READ(5,502) NUM,MACHS,PRS0T,TMP0,PTHW,CHI
      IF(MACHS.EQ.0.0) WRITE(6,505)
      IF(MACHS.EQ.0.0) STOP
      Q1 = 13.6*9.806
      Q2 = 0.017453293
      ALPHA = 0.0
      BETA = 0.0
      ISOL = 1
      DISP=0.0
      IOUT=1
      PTHWP=PTHW+CHI
      THETAW=PTHW*Q2
      PRS0=PRS0T*Q1
      TMP0=TMP0+273.16

C     SET ALL STATES INITIALLY AT CHOSEN STATE
      IF(IREAL.EQ.2) GOTO 60
      ISTAT0=IST0
      ISTAT1=IST1
      ISTAT2=IST2
      ISTAT3=IST3
      ISTAT4=IST4
      ISTAT5=IST5
      GOTO 70
60    ISTAT0=1
      ISTAT1=1
      ISTAT2=1
      ISTAT3=1
      ISTAT4=1
      ISTAT5=1
C
C    ISOL = 1     WEAK SOLUTION
C    ISOL =-1     STRONG SOLUTION

C      ****   TO OBTAIN RR SOLUTION   ****

70    CALL RR(MACHS,THETAW,MACH0,PRS0,TMP0,PHI01,MACH1,PRS1,TMP1,PHI11,PH
     1I12,MACH2,PRS2,TMP2,DISP,ISOL,IOUT,ILL)
C     IF(ILL.EQ.100)WRITE(6,503)

C      ****   TO OBTAIN MR-SOLUTION   ****
C
      IF(ILL.EQ.100.AND.IQ.EQ.0) CALL SIMMR(NUM,MACHS,PRS0,TMP0,PTHW)
      IF(ILL.EQ.100.AND.IQ.EQ.1) CALL SIMMR(NUM,MACHS,PRS0,TMP0,PTHWP)
      IF(ILL.EQ.100) GOTO 1
      IF(ILL.EQ.999)WRITE(6,504)
      IF(ILL.EQ.999)GOTO 1

C     OUTPUT FOR RR RESULTS
      DP0 = PRS0
      DP1 = PRS1
      DP2 = PRS2
      DT0 = TMP0
      DT1 = TMP1
      DT2 = TMP2
      CALL GAS(DP0,DT0,DUM,DRHO0,DUM,DA0,DUM,ISTAT0)
      CALL GAS(DP1,DT1,DUM,DRHO1,DUM,DA1,DUM,ISTAT1)
      CALL GAS(DP2,DT2,DUM,DRHO2,DUM,DA2,DUM,ISTAT2)
      P0 = PRS0/Q1
```

```
      P1 = PRS1/Q1
      P2 = PRS2/Q1
      WRITE(6,601) NUM,MACHS,PTHW,ISOL,IREAL,IGAS
      WRITE(6,609)ISTAT0,ISTAT1,ISTAT2
      WRITE(6,602)
      WRITE(6,603) MACH0,MACH1,MACH2
      WRITE(6,604) P0,P1,P2
      WRITE(6,605) TMP0,TMP1,TMP2
      WRITE(6,607) DRHO0,DRHO1,DRHO2
      WRITE(6,608) DA0,DA1,DA2
      P0 = 90.0-THETAW/Q2
      T1 = P0-PHI01/Q2
      P1 = PHI1/Q2
      T2 = (PHI1-PHI12)/Q2
      W = P1-T1
      D = PTHWP+90.-W
C     P0 (PHI0) / T1 (THETA1) / P1 (PHI1) / T2 (THETA2) / W (OMEGA) /
C     D (DELTA)
      WRITE(6,606) P0,T1,D,P1,T2,W
      MA(1)=MACH1
      MA(2)=MACH2
      PR(1)=PRS1
      PR(2)=PRS2
      TM(1)=TMP1
      TM(2)=TMP2
      PH(1)=P0
      PH(2)=P1
      TH(1)=T1
      TH(2)=T2
      IST(1)=ISTAT1
      IST(2)=ISTAT2
      DO 80 I=1,2
      CALL VIB(IGAS,PR(I),TM(I),TAU)
      DPR=PR(I)
      DTM=TM(I)
      CALL GAS(DPR,DTM,DUM,DUM,DUM,AS,DUM,IST(I))
      V2=MA(I)*AS*SIN((PH(I)-TH(I))*3.14159/180.)
      VRL(I)=TAU*V2*1.E-06*1000.
80    CONTINUE
      WRITE(6,610) (VRL(I),I=1,2)
      IF(MACHS.EQ.0)GOTO 85
      GOTO 1
C
  501 FORMAT(4I2,2X,2F6.1)
  502 FORMAT(I5,5F10.3)
C 503 FORMAT(5X,'NO SOLUTION FOR RR')
  504 FORMAT(5X,'SOLUTION DID NOT CONVERGE')
  505 FORMAT(1H1)
506   FORMAT(6I2)
  601 FORMAT(1H ,///,' EXP=',I4,3X,'****** RR-SOLUTION AT MACHS=',F7.3,
     13X'THETAW=',F6.2,' (DEG)  ISOL=',I2,3X,'IREAL='
     1,I2,3X,'IGAS=',I2)
  602 FORMAT(1H ,/,9X,'** REGION **',16X,'0',15X,'1',15X,'2')
  603 FORMAT(1H ,/,9X,'MACH',18X,4(F8.4,8X))
  604 FORMAT(1H ,7X,'PRESSURE (TORR)', 9X,4(F8.2,8X))
  605 FORMAT(1H ,6X,'TEMPERATURE (DEG K)',6X,4(F8.2,8X))
  606 FORMAT(1H ,/,15X,'PHI0=',F8.4,' (DEG)   THETA1=',F8.4,' (DEG)    DEL
     1TA=',F8.4,' (DEG)',/,15X,'PHI1=',F8.4,' (DEG)   THETA2=',F8.4,
     2' (DEG)   OMEGA=',F8.4,' (DEG)')
  607 FORMAT(1H ,7X,' DENSITY (KG/M**3)',7X,4(F10.7,6X))
  608 FORMAT(1H ,7X,' S. SPEED (M/SEC)',6X,4(F8.1,8X))
609   FORMAT(1H ,/,9X,'** STATE  **',16X,I1,15X,I1,15X,I1)
610   FORMAT(7X,'VIB. R.L.  (MM) IN REGIONS 1 & 2 = ',2F10.6)
   85 STOP
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  GAS  ***
C     ------------------------------------------------------------------


      SUBROUTINE GAS(P,T,G,RHO,H,A,MASS,ISTATE)

C  --  THIS SUBROUTINE IS DOUBLE-PRECISION  --
C
      IMPLICIT REAL*8(A-H,M,O-Z)
      DIMENSION AMASS(7),AG(7),TCO2(4),TSF6(6),AG1(7)
      COMMON IREAL,IGAS,GO,ALPHA,BETA
      DATA AMASS/28.967D0,28.0134D0,39.944D0,44.010D0,146.06D0,146.06D0,
     128.967D0/
      DATA AG1/1.4D0,1.4D0,1.667D0,1.29D0,1.093D0,1.333D0,1.4D0/
      DATA AG/1.4D0,1.4D0,1.667D0,1.4D0,1.333D0,1.02D0,1.4D0/
      DATA TSF6/1114.5D0,954.8D0,1380.5D0,884.4D0,753.5D0,522.0D0/
      DATA TCO2/960.2D0,960.3D0,1932.2D0,3380.3D0/
C        IREAL=0   FROZEN
C        IREAL=1   PERFECT (CONSTANT GAMMA)
C        IREAL=2   EQUILIBRIUM (INCL. VIB.)
C        IGAS=1    AIR
C        IGAS=2    NITROGEN
C        IGAS=3    ARGON
C        IGAS=4    CO2
C        IGAS=5    SF6
C        IGAS=6    GAMMA=1.333
C        IGAS=7    ONLY OXYGEN IS EXCITED IN AIR
C        ISTATE=0  FLOW IS AT CHOSEN STATE
C        ISTATE=1  FLOW IS AT VIB. EQUILIBRIUM
C
      RR = 8.3201D3
      MASS = AMASS(IGAS)
      TOX = 2230.0
      TN = 3340.0
      GO = AG(IGAS)
      IF(IREAL.EQ.1) GO=AG1(IGAS)
C
      MASS = MASS*(1.0+ALPHA)
      G = (GO+ALPHA*BETA)/(1.0+ALPHA*BETA)
      H = G/(G-1.0)*RR/MASS*T
C
      IF(ISTATE.EQ.1) GOTO 5
      IF(IREAL.NE.2) GO TO 200
5     GO TO(10,20,30,40,50,60,70),IGAS
```

```
C
   10 V = (TOX/T)**2*DEXP(TOX/T)/(DEXP(TOX/T)-1.0)**2*0.21+(TN/T)**2*
     1DEXP(TN/T)/(DEXP(TN/T)-1.0)**2*0.79
      H = (3.5*T+TOX/(DEXP(TOX/T)-1.0)*0.21+TN/(DEXP(TN/T)-1.0)*0.79+
     12.5*ALPHA*BETA*T)*RR/MASS
      G1 = (3.5+V)/(2.5+V)
      GO TO 100
C
   20 V = (TN/T)**2*DEXP(TN/T)/(DEXP(TN/T)-1.0)**2
      H = (3.5*T+TN/(DEXP(TN/T)-1.0)+2.5*ALPHA*BETA*T)*RR/MASS
      G1 = (3.5+V)/(2.5+V)
      GO TO 100
C
   30 GO TO 200
C
   40 V = 0.0
      H = 3.5*T
      DO 41 I = 1,4
      V = V+(TCO2(I)/T)**2*DEXP(TCO2(I)/T)/(DEXP(TCO2(I)/T)-1.0)**2
      H = H+TCO2(I)/(DEXP(TCO2(I)/T)-1.0)
   41 CONTINUE
      H = (H+2.5*ALPHA*BETA*T)*RR/MASS
      G1 = (3.5+V)/(2.5+V)
      GO TO 100
C
   50 V = 0.0
      H = 4.0*T
      DO 51 I = 1,6
      IFACT = I
      IF(I.GT.3) IFACT = 3
      V = V+(TSF6(I)/T)**2*DEXP(TSF6(I)/T)/(DEXP(TSF6(I)/T)-1.0)**2*IFAC
     1T
      H = H+TSF6(I)/(DEXP(TSF6(I)/T)-1.0)*IFACT
   51 CONTINUE
      H = (H+3.0*ALPHA*BETA*T)*RR/MASS
      G1 = (4.0+V)/(3.0+V)
      GO TO 100
C
   60 GO TO 200
C
   70 V = (TOX/T)**2*DEXP(TOX/T)/(DEXP(TOX/T)-1.0)**2*0.21
      H = (3.5*T+TOX/(DEXP(TOX/T)-1.0)*0.21+2.5*ALPHA*BETA*T)*RR/MASS
      G1 = (3.5+V)/(2.5+V)
      GO TO 100
C
  100 G = (G1/(G1-1.0)+1.0/(G0-1.0)*ALPHA*BETA)/(1.0/(G1-1.0)+1.0/(G0-1.
     10)*ALPHA*BETA)
C
  200 RHO = P/T*MASS/RR
      A = DSQRT(G*P/RHO)

      RETURN
      END
```



```
C     ------------------------------------------------------------------
C                  ***  SUBROUTINE SUB-PROGRAM  INIT  ***
C     ------------------------------------------------------------------


      SUBROUTINE INIT(PRSO,TMPO,THETAW,MACHS,GSO,GSI1,GSI2,PSTEP)

      REAL MACHS
      DOUBLE PRECISION DP,DT,DG,DAMW
      COMMON /STATE/MATO,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5
      Q2 = 0.01745329

      DP = DBLE(PRSO)
      DT = DBLE(TMPO)
      CALL GAS(DP,DT,DG,DAMW1,DAMW2,DAMW3,DAMW4,DAMW5,ISTAT)
      GAMMA = SNGL(DG)
      IF(GAMMA.LT.1.1) GO TO 10
      TCHI = 30.70*Q2-0.75*THETAW
      IF(THETAW.GT.2.0*Q2) TCHI = 29.85*Q2-1.165*THETAW+0.013/Q2*THETAW**2
      TFACT = 1.0-0.214*(MACHS-1.6)
      IF(MACHS.GT.2.0) TFACT = 0.812-0.110*(MACHS-2.0
      IF(MACHS.GT.3.0) TFACT = 0.563-0.036*(MACHS-3.0
      IF(MACHS.GT.5.0) TFACT = 0.352-0.008*(MACHS-5.0
      TCHI = TCHI*TFACT
      IF(MACHS.GE.1.6) TFACT = 1.0-0.11*SQRT(MACHS-1.6 )*(1.4-GAMMA)
      IF(MACHS.LT.1.6) TFACT = 1.0+0.11*SQRT(1.6-MACHS )*(1.4-GAMMA)
      TCHI = TCHI*TFACT
      TCHI = TCHI-6.5*Q2*(1.4-GAMMA)
      GO TO 20
   10 TCHI = 29.85*Q2-1.165*THETAW+0.013/Q2*THETAW**2
      TFACT = 1.0-0.47*(MACHS-1.6)
      IF(MACHS.GT.2.0) TFACT = 0.812-0.25*(MACHS-2.0)
      IF(MACHS.GT.3.0) TFACT = 0.563-0.106*(MACHS-3.0)
      IF(MACHS.GT.5.0) TFACT = 0.352-0.036*(MACHS-5.0)
      TCHI = TCHI*TFACT
      TFACT = 1.0+0.11*(MACHS-1.6)*(GAMMA-1.02)/0.08
      TCHI = TCHI*TFACT
   20 IF(TCHI.LT.1.0*Q2) TCHI = 1.0*Q2
      CSTEP = TCHI*0.2
C
      TPHI0 = (76.48+25.446/(MACHS-0.68))*Q2
      TPHI0 = TPHI0-(1.72-0.45/(MACHS-0.80))*(THETAW-5.0*Q2)
      TPHID = (64.1-101.0/SQRT(MACHS+1.0))*Q2+0.6*(THETAW-5.0*Q2)-0.0167
     1*(THETAW/Q2-5.0)**2*SQRT((ABS(MACHS-1.6)))*Q2
      TFACT = 0.0
      IF(GAMMA.LT.1.4) TFACT =  ((1.4-GAMMA)*10.0)**1.5/8.0
      IF(GAMMA.GT.1.4) TFACT = -((GAMMA-1.4)*10.0)**1.5/8.0
      TPHI1= TPHI0-TPHID*TFACT
      IF(TPHI1.LT.5.0*Q2) TPHI1 = 5.0*Q2
      PSTEP = 4.0*Q2
C
      RETURN
      END
```

```
C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  MAXTHE  ***
C     ------------------------------------------------------------------

      SUBROUTINE MAXTHE(MACH1,PRS1,TMP1,PHI1,THETAM,MACH2,PRS2,TMP2,ILL)

      DIMENSION THETA(3),G(2)
      REAL MACH1,MACH2
      FACT21 = 0.005
      FACT22 = 1.0E-5
      Q2 = 0.017453293
C
C  ---  SET THE INITIAL VALUE FOR PHI1  ---
C
      TRR = 0.0
      DO 5 I = 1,4
      PP = (45.0+I*10.0)*Q2
      CALL SVFS(MACH1,PRS1,TMP1,PP,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      IF(ILL.NE.0) GO TO 102
      IF(PP-PHI12.LT.TRR) GO TO 5
      TRR = PP-PHI12
      TPHI = PP
    5 CONTINUE
      TPHIF = TPHI
      STEP = 3.0*Q2
      K = 0
C
C  ---  START ITERATION  ---
C
   10 IF(MACH1*SIN(TPHI-STEP).GT.1.0) GO TO 11
      STEP = 0.4*TPHIF
      TPHI = TPHIF*0.44
      TPHIF = TPHI
   11 DO 20 I = 1,3
      PP = TPHI+(I-2)*STEP
      CALL SVFS(MACH1,PRS1,TMP1,PP,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      IF(ILL.NE.0) GO TO 101
      THETA(I) = PP-PHI12
   20 CONTINUE
C
      G(1) = THETA(2)-THETA(1)
      G(2) = THETA(3)-THETA(2)
C
      IF(G(1)*G(2).GT.0.0) GO TO 21
      IF(STEP.LT.FACT22) GO TO 30
      IF(ABS(G(1)).LT.STEP*FACT21.AND.ABS(G(2)).LT.STEP*FACT21) GO TO 30
      GO TO 22
C
   21 IF(ABS(G(1)-G(2)).LE.ABS(G(2)*STEP/1.67)) GO TO 22
C
      TPHIF = TPHI
      TPHI = TPHI+(G(1)+G(2))/2.0/(G(1)-G(2))*STEP
      STEP = ABS((G(1)+G(2))/2.0/(G(1)-G(2))*STEP)
   22 STEP = STEP*0.30
      K = K+1
      IF(K.GT.20) GO TO 40
      GO TO 10
C
   30 ILL = 0
      PHI1 = TPHI
      THETAM = THETA(2)
      RETURN
C
   40 ILL = 999
      RETURN
C
  101 WRITE(6,601)
  601 FORMAT(1H ,'(STOPPED AT MAXTHE 101)')
      GO TO 1000
  102 WRITE(6,602)
  602 FORMAT(1H ,'(STOPPED AT MAXTHE 102)')
 1000 ILL = 999
      RETURN
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  NR  ***
C     ------------------------------------------------------------------

      SUBROUTINE NR(MACHS,PRS0,TMP0,THEMIN,IC,IOUT,ILL)

      REAL MACH0,MACHS,MACH1
      DIMENSION AM(3)
C
      Q2 = 0.017453293
      FACT = 1.0E-4
      GO TO (10,50),IC
C
   10 TTHE = 30.0*Q2
      STEP = 0.2*TTHE
      K = 0
C
C  ---  START ITERATION  ---
C
   20 DO 30 I = 1,3
      TT = TTHE+(I-2)*STEP
      PHI0 = 90.0*Q2-TT
      MACH0 = MACHS/SIN(PHI0)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 101
      AM(I) = MACH1
   30 CONTINUE
C
      IF(ABS(AM(2)-1.0).LT.FACT) GO TO 40
      TTHE = TTHE+(AM(2)-1.0)*STEP*2.0/(AM(1)-AM(3))
      STEP = 0.3*ABS((AM(2)-1.0)*STEP*2.0/(AM(1)-AM(3)))
      IF(STEP.GT.20.0*Q2) GO TO 102
      K = K+1
      IF(K.GT.25) GO TO 103
```

```
      GO TO 20
C
   40 ILL = 0
      THEMIN = TTHE
      PRTTHE = TTHE/Q2
      IF(IOUT.EQ.0) RETURN
      WRITE(6,604) MACHS,PRTTHE
  604 FORMAT(1H ,//,'*****  NR-MR BOUNDARY AT MACHS=',F5.2,' IS AT THETA
     1 WALL PRIME =',F8.4,' (DEG)')
      RETURN
C
   50 THETAW = MACHS
      PRTTHE = THETAW/Q2
      PHI0 = 90.0*Q2-THETAW
      MACH0 = 1.5/SIN(PHI0)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 102
      IF(MACH1.LT.1.0) GO TO 60
      THEMIN = 1.5
      IF(IOUT.EQ.0) RETURN
      WRITE(6,605) PRTTHE
  605 FORMAT(1H ,//,'*****  NO NR-MR BOUNDARY AT THETA WALL PRIME =',F8.
     14,' (DEG)')
      ILL = 0
      RETURN
C
   60 RM = 1.2
      RMF = RM
      STEP = 0.05
      PHI0 = 90.0*Q2-THETAW
      K = 0
C
C  ---  START ITERATION  ---
C
   70 DO 80 I = 1,3
      RMM = RM+(I-2)*STEP
      MACH0 = RMM/SIN(PHI0)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 101
      AM(I) = MACH1
   80 CONTINUE
C
      IF(ABS(AM(2)-1.0).LT.FACT) GO TO 90
      RM = RM+(AM(2)-1.0)*STEP*2.0/(AM(1)-AM(3))
      STEP = 0.3*ABS((AM(2)-1.0)*STEP*2.0/(AM(1)-AM(3)))
      IF(RM+STEP.LT.1.5) GO TO 85
      STEP = 0.4*(1.5-RMF)
      RM = 1.5-STEP*1.1
   85 IF(RM-STEP.GT.1.0) GO TO 86
      STEP = 0.4*(RMF-1.0)
      RM = 1.0+1.1*STEP
   86 RMF = RM
      K = K+1
      IF(K.GT.25) GO TO 103
      GO TO 70
C
   90 ILL = 0
      THEMIN = RM
      IF(IOUT.EQ.0) RETURN
      WRITE(6,606) PRTTHE,RM
  606 FORMAT(1H ,//,'****  NR-MR BOUNDARY AT THETA WALL PRIME =',F8.3,'
     1(DEG) IS AT MACHS =',F6.3)
      RETURN
C
  101 WRITE(6,601)
  601 FORMAT(1H ,'(STOPPED AT NR 101)')
      GO TO 1000
  102 WRITE(6,602)
  602 FORMAT(1H ,'(STOPPED AT NR 102)')
      GO TO 1000
  103 WRITE(6,603)
  603 FORMAT(1H ,'(STOPPED AT NR 103)')
 1000 ILL = 999
      RETURN
C
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  RR  ***
C     ------------------------------------------------------------------


      SUBROUTINE RR(MACHS,THETAW,MACH0,PRS0,TMP0,PHI01,MACH1,PRS1,TMP1,P
     1HI1,PHI12,MACH2,PRS2,TMP2,DISP,ISOL,IOUT,ILL)

      DIMENSION T(3)
      REAL MACHS,MACH0,MACH1,MACH2
C
      Q2 = 0.017453293
      FACT = 0.01*Q2
C
C  ---  SET INITIAL VALUE FOR PHI1  ---
C
      MACH0 = MACHS/COS(THETAW)
      PHI0 = 90.0*Q2-THETAW
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,1,ILL,1)
      IF(ILL.NE.0) GO TO 101
      CALL MAXTHE(MACH1,PRS1,TMP1,PHI1M,THETAM,MACH2,PRS2,TMP2,ILL)
      IF(ILL.NE.0) GO TO 102
      THETA1 = PHI0-PHI01
      IF(THETA1-THETAM-DISP.LT.0.0) GO TO 5
      PTHE1 = THETA1/Q2
      PTHEM = THETAM/Q2
      PDISP = DISP/Q2
      ILL = 100
      IF(IOUT.EQ.0) RETURN
C     WRITE(6,610) PTHE1,PTHEM,PDISP
      RETURN
C
    5 TPHI1 = PHI1M-2.0*Q2
      STEP = 0.3*Q2
```

```
      K = 0
C
C  ---  START ITERATION  ---
C
   10 IF(TPHI1*ISOL-STEP.LT.PHI1M*ISOL) GO TO 15
      STEP = ABS(TPHIF-PHI1M)*0.4
      TPHI1 = PHI1M-ISOL*STEP*1.2
   15 IF(TPHI1-STEP.GT.0.0) GO TO 16
      STEP = TPHIF*0.4
      TPHI1 = STEP*1.2
   16 DO 20 I = 1,3
      PP = TPHI1+(I-2)*STEP
      CALL SVFS(MACH1,PRS1,TMP1,PP,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      IF(ILL.NE.0) GO TO 103
      T(I) = PP-PHI12-(PHI0-PHI01)+DISP
   20 CONTINUE
C
      IF(ABS(T(2)).LT.FACT) GO TO 40
      TPHIF = TPHI1
      IF(T(1).EQ.T(3)) GO TO 25
      TPHI1 = TPHI1+T(2)*STEP*2.0/(T(1)-T(3))
      STEP = 0.4*ABS(T(2)*STEP*2.0/(T(1)-T(3)))
      IF(STEP.LT.20.0*Q2) GO TO 30
      STEP = 20.0*Q2
      TPHI1 = TPHIF+STEP*(T(2)/(T(1)-T(3)))/ABS(T(2)/(T(1)-T(3)))
      GO TO 30
   25 STEP = STEP*2.0
   30 K = K+1
      IF(K.GT.25) GO TO 105
      GO TO 10
C
   40 PHI1 = TPHI1
      CALL SVFS(MACH1,PRS1,TMP1,PHI1,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      ILL = 0
      RETURN
C
  101 WRITE(6,601)
      GO TO 1000
  102 WRITE(6,602)
      GO TO 1000
  103 WRITE(6,603)
      GO TO 1000
  105 WRITE(6,605)
      GO TO 1000
 1000 ILL = 999
      RETURN
C
  601 FORMAT(1H ,'(STOPPED AT RR 101)')
  602 FORMAT(1H ,'(STOPPED AT RR 102)')
  603 FORMAT(1H ,'(STOPPED AT RR 103)')
  605 FORMAT(1H ,'(STOPPED AT RR 105)')
C 610 FORMAT(1H ,//,5X,'NO RR-SOLUTION',5X,'THETA1=',F8.4,' (DEG)   THET
C    1AM=',F8.4,' (DEG)   DISP=',F7.4,' (DEG)')
C
      END
```



```
C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  RRMR  ***
C     ------------------------------------------------------------------

      SUBROUTINE RRMR(MACHS,MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,M
     1ACH2,PRS2,TMP2,PHI1,PHI12,THETW0,THEMIN,DISP,K,ICASE,ILL)

      DIMENSION T(3),APHI1(3)
      REAL MACHS,MACH0,MACH1,MACH2,MACHMX
C
      Q2 = 0.017453293
      FACT01 = 1.0E-4
      FACT02 = 1.0E-4
      GO TO (5,40),ICASE
C
C  ---  SET INITIAL VALUE FOR THETA WALL  ---
C
    5 THETAW = 50.0
      TPHI = (90.0-THETAW)*Q2
      TPHIF = TPHI
      STEP = TPHI*0.1
      K = 0
C
C  ---  START THE ITERATION  ---
C
   10 IF(TPHI+STEP.LT.90.0*Q2-THEMIN) GO TO 11
      STEP = 0.4*(90.0*Q2-THEMIN-TPHIF)
      TPHI = 90.0*Q2-THEMIN-STEP*1.1
      TPHIF = TPHI
   11 DO 20 I = 1,3
      PP = TPHI+(I-2)*STEP
      MACH0 = MACHS/SIN(PP)
C
      CALL SVFS(MACH0,PRS0,TMP0,PP,MACH1,PRS1,TMP1,PHI01,1,ILL,1)
      IF(ILL.NE.0) GO TO 101
      CALL MAXTHE(MACH1,PRS1,TMP1,PHI1,THETAM,MACH2,PRS2,TMP2,ILL)
      IF(ILL.NE.0) GO TO 102
      T(I) = THETAM-(PP-PHI01)-DISP
      APHI1(I) = PHI1
   20 CONTINUE
C
      IF(ABS(T(2)).LT.FACT01) GO TO 30
      IF((T(3)-T(1)).EQ.0.0) GO TO 25
      TPHIF = TPHI
      TPHI = TPHI+T(2)*STEP*2.0/(T(1)-T(3))
      STEP = ABS(T(2)*STEP*2.0/(T(1)-T(3)))
   25 STEP = STEP*0.3
      IF(STEP.GT.20.0*Q2) GO TO 104
      K = K+1
      IF(K.GT.25) GO TO 103
      GO TO 10
C
   30 ILL = 0
      MACH0 = MACHS/SIN(TPHI)
      PHI0 = TPHI
```

```
      PHI1 = APHI1(2)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,1,ILL,1)
      CALL SVFS(MACH1,PRS1,TMP1,PHI1,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      THETW0 = 90.0*Q2-PHI0
      RETURN
C
   40 PHI0 = 90.0*Q2-THETW0
      MACHMX = THEMIN
C
C  ---  SET INITIAL VALUE FOR MACHS  ---
C
      TM = 1.2/SIN(PHI0)
      TMF = TM
      STEP = 0.03/SIN(PHI0)
      K = 0
C
C  ---  START THE ITERATION  ---
C
   50 IF((TM-STEP)*SIN(PHI0).GT.1.0) GO TO 51
      STEP = (TMF-1.0/SIN(PHI0))*0.4
      TM = 1.0/SIN(PHI0)+1.1*STEP
   51 IF(TM+STEP.LT.MACHMX/SIN(PHI0)) GO TO 52
      STEP = (MACHMX/SIN(PHI0)-TMF)*0.4
      TM = MACHMX/SIN(PHI0)-1.1*STEP
   52 TMF = TM
      DO 60 I = 1,3
      TMM = TM+(I-2)*STEP
      CALL SVFS(TMM,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,1,ILL,1)
      IF(ILL.NE.0) GO TO 101
      CALL MAXTHE(MACH1,PRS1,TMP1,PHI1,THETAM,MACH2,PRS2,TMP2,ILL)
      IF(ILL.NE.0) GO TO 102
      T(I) = THETAM-(PHI0-PHI01)
      APHI1(I) = PHI1
   60 CONTINUE
C
      IF(ABS(T(2)).LT.FACT02) GO TO 70
      IF((T(3)-T(1)).EQ.0.0) GO TO 65
      TM = TM+STEP*2.0*T(2)/(T(1)-T(3))
      STEP = ABS(STEP*2.0*T(2)/(T(1)-T(3)))
   65 STEP = 0.30*STEP
      IF(STEP.GT.0.2) GO TO 104
      K = K+1
      IF(K.GT.25) GO TO 103
      GO TO 50
C
   70 ILL = 0
      MACH0 = TM
      MACHS = TM*SIN(PHI0)
      PHI1 = APHI1(2)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,1,ILL,1)
      CALL SVFS(MACH1,PRS1,TMP1,PHI1,MACH2,PRS2,TMP2,PHI12,1,ILL,2)
      RETURN
C
  101 WRITE(6,602)
  602 FORMAT(1H ,'(STOPPED AT RRMR 101)')
      GO TO 1000
  102 WRITE(6,603)
  603 FORMAT(1H ,'(STOPPED AT RRMR 102)')
      GO TO 1000
  103 WRITE(6,604)
  604 FORMAT(1H ,'(STOPPED AT RRMR 103)')
      GO TO 1000
  104 WRITE(6,608)
  608 FORMAT(1H ,'(STOPPED AT RRMR 104)')
 1000 ILL = 999

      RETURN
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  SIMMR  ***
C     ------------------------------------------------------------------


      SUBROUTINE SIMMR(NUM,MACHS,PRS0,TMP0,PTHWP)

      REAL MACH0,MACHS,MACH1,MACH2,MACH3,MACHK,MA(3)
      DOUBLE PRECISION ALPHA,BETA,G0,DP1,DP2,DP3,DT1,DT2,DT3,DR0,DR1,
     1DR2,DR3,DA1,DA2,DA3,DPR,DTM,AS
      DIMENSION PR(3),TM(3),PH(3),TH(3),IST(3),VEL(3)
      COMMON IREAL,IGAS,G0,ALPHA,BETA,IP,IQ
      COMMON /C1/SLIP
      COMMON /ST/ISTAT0,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5
C
      Q1 = 13.6*9.806
      Q2 = 0.017453293
      SLIP = 0.0
      ALPHA = 0.0
      BETA = 0.0
      L=0

      IF(IQ.EQ.1) GOTO 5
C     IQ = 0 , THETA WALL AS THE PARAMETER
      PTHW=PTHWP
      THETAW=PTHW*Q2
      CALL NR(MACHS,PRS0,TMP0,THEMIN,1,0,ILL)
      CALL TRPL1(THETAW,MACHS,PRS0,TMP0,CHI,PHI,MACH2,MACHK,PHIK,
     1THEMIN,DELTA,PHI3,CHIP,2,ILL)
      GOTO 55

C     IQ = 1 , THETA WALL PRIME AS THE PARAMETER
5     THEWP=PTHWP*Q2
      CALL NR(MACHS,PRS0,TMP0,THEMIN,1,0,ILL)
      CALL RRMR(MACHS,MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,
     1MACH2,PRS2,TMP2,PHI1,PHI12,THETW0,THEMIN,0.0,K,1,ILL)
      THETW1=2.*Q2
      THETW3=THETW0
      CALL TRPL1(THETW1,MACHS,PRS0,TMP0,CHI1,PHI,MACH2,MACHK,PHIK,
     1THEMIN,DELTA,PHI3,CHIP,2,ILL)
      CALL TRPL1(THETW3,MACHS,PRS0,TMP0,CHI3,PHI,MACH2,MACHK,PHIK,
     1THEMIN,DELTA,PHI3,CHIP,2,ILL)
```

```
      THEWP1=THETW1+CHI1
      THEWP3=THETW3+CHI3
      THETW2=0.5*(THETW1+THETW3)
10    CALL TRPL1(THETW2,MACHS,PRS0,TMP0,CHI2,PHI,MACH2,MACHK,PHIK,
     1THEMIN,DELTA,PHI3,CHIP,2,ILL)
      THEWP2=THETW2+CHI2
C     WRITE(6,506)THEWP,THEWP2
      IF(ABS(THEWP2-THEWP).LT.0.1*Q2) GOTO 50
      IF(THEWP.GT.THEWP2) GOTO 30
      THETW3=THETW2
      GOTO 40
30    THETW1=THETW2
40    THETW2=0.5*(THETW1+THETW3)
      L=L+1
      IF(L.GT.25) WRITE(6,505)
      IF(L.GT.25) GOTO 60
      GOTO 10
50    THETAW=THETW2
      CHI=CHI2
      PTHW=THETAW/Q2

55    IF(ILL.NE.0) WRITE(6,503)
      IF(ILL.NE.0) GOTO 70
      PCHI = CHI/Q2
      PCHIP=CHIP/Q2
      PTHEWP=PTHW+PCHI
      PDELTA = DELTA/Q2
      PWP = 90.0-(DELTA-THETAW-CHI)/Q2
      PHI0 = 90.0*Q2-THETAW-CHI
      PHI3 = 90.0*Q2-CHI
      PHI1 = PHI
      MACH0 = MACHS/SIN(PHI0)
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,2,ILL,1)
      CALL SVFS(MACH1,PRS1,TMP1,PHI1,MACH2,PRS2,TMP2,PHI12,2,ILL,2)
      CALL SVFS(MACH0,PRS0,TMP0,PHI3,MACH3,PRS3,TMP3,PHI33,2,ILL,3)
      DP1= PRS1
      DP2= PRS2
      DP3= PRS3
      DT1= TMP1
      DT2= TMP2
      DT3= TMP3
      CALL GAS(PRS0,TMP0,DUM,DR0,DUM,DUM,DUM,ISTAT0)
      CALL GAS(DP1,DT1,DUM,DR1,DUM,DA1,DUM,ISTAT1)
      CALL GAS(DP2,DT2,DUM,DR2,DUM,DA2,DUM,ISTAT2)
      CALL GAS(DP3,DT3,DUM,DR3,DUM,DA3,DUM,ISTAT3)
      P1 = PRS1/Q1
      P2 = PRS2/Q1
      P3 = PRS3/Q1
      T1 = (PHI0-PHI01)/Q2
      T2 = (PHI1-PHI12)/Q2
      T3 = (PHI3-PHI33)/Q2
      PH0 = PHI0/Q2
      PH1 = PHI1/Q2
      PH3 = PHI3/Q2
      PRS0= PRS0/Q1
      WRITE(6,601)NUM,MACHS,PTHEWP,ILL,IREAL,IGAS,PRS0,TMP0,DR0,
     1PCHI,PTHW,PCHIP,PDELTA,PWP,MACHK
      WRITE(6,608) ISTAT1,ISTAT2,ISTAT3
      WRITE(6,604) MACH1,MACH2,MACH3
      WRITE(6,602) P1,P2,P3
      WRITE(6,605) TMP1,TMP2,TMP3
      WRITE(6,607) DR1,DR2,DR3
      WRITE(6,610) DA1,DA2,DA3
      WRITE(6,603) T1,T2,T3
      WRITE(6,606) PH0,PH1,PH3
      THEWPP=THETAW+CHIP
      MA(1)=MACH1
      MA(2)=MACH2
      MA(3)=MACH3
      PR(1)=PRS1
      PR(2)=PRS2
      PR(3)=PRS3
      TM(1)=TMP1
      TM(2)=TMP2
      TM(3)=TMP3
      PH(1)=PH0
      PH(2)=PH1
      PH(3)=PH3
      TH(1)=T1
      TH(2)=T2
      TH(3)=T3
      IST(1)=ISTAT1
      IST(2)=ISTAT2
      IST(3)=ISTAT3
      DO 60 I=1,3
      CALL VIB(IGAS,PR(I),TM(I),TAU)
      DPR=PR(I)
      DTM=TM(I)
      CALL GAS(DPR,DTM,DUM,DUM,DUM,AS,DUM,IST(I))
      V2=MA(I)*AS*SIN((PH(I)-TH(I))*3.14159/180.)
      VRL(I)=TAU*V2*1.E-06*1000.
60    CONTINUE
      WRITE(6,609)(VRL(I),I=1,3)
      CALL TRPL2(MACH1,PRS1,TMP1,PHI1,PHI01,THEWPP)
  503 FORMAT(5X,'ILL IN TRPL1 IS NOT ZERO')
  505 FORMAT(5X,'ITERATION MORE THAN 25 TIMES')
C 506 FORMAT(5X,'THEWP,THEWP2 : ',2F10.5)
  601 FORMAT(/,1H ,'EXP=',I4,3X,'******  MR-SOLUTION AT MACHS=',F7.3,3X,
     1'THETWAP=',F6.2,3X,'ILL=',I3,/,9X,'IREAL=',I2,3X,'IGAS=',I2,
     23X,'P0=',F8.2,' (TORR)',3X,'T0=',
     1F8.2,' (DEG)',3X,'RHO0=',F10.7,' (KG/M**3)',/9X
     1'CHI=',F7.3,3X,'THETAW=',F6.2,3X,'CHIP=',F7.3,3X,'DELTA=',F8.3,
     13X,'OMEGA PRIME=',F8.3,3X,'MACHK=',F7.3,
     1//,9X,'** REGION **',9X,'1',11X,'2',
     111X,'3')
  602 FORMAT(1H ,10X,'PRESSURE',6X,3(F9.2,3X))
  605 FORMAT(1H ,10X,'TEMPERATURE',3X,3(F9.2,3X))
  604 FORMAT(1H ,10X,'MACH',11X,3(F7.3,5X))
  603 FORMAT(1H ,10X,'THETA',10X,3(F7.3,5X))
  606 FORMAT(1H ,10X,'PHI',12X,3(F7.3,5X))
  607 FORMAT(1H ,8X,'DENSITY (KG/M**3)',3(F10.7,2X))
608   FORMAT(1H ,8X,'** STATE  **',9X,I1,11X,I1,11X,I1,/)
```

```
609   FORMAT(1H ,7X,'VIB. R.L.(MM) IN REGIONS 1, 2 & 3 = ',3(F10.4,2X))
610   FORMAT(1H ,10X,'SOUND SPEED',4X,3(F8.2,4X))
 70   RETURN
      END


C     ------------------------------------------------------------------
C                  ***  SUBROUTINE SUB-PROGRAM  SVFS  ***
C     ------------------------------------------------------------------


      SUBROUTINE SVFS(SMACH1,SPRS1,STMP1,SPHI1,SMACH2,SPRS2,STMP2,SPHI2,
     1IC,ILL,IREGIN)

      IMPLICIT REAL*8(A-H,M,O-R,T-Z)
      DOUBLE PRECISION A3(3,2),A4(3,2)
      COMMON IREAL,IGAS,GO,ALPHA,BETA,IP
      COMMON /ST/ISTAT0,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5

C     IREGIN 1   FLOW REGIONS (0) & (1)
C     IREGIN 2   FLOW REGIONS (1) & (2)
C     IREGIN 3   FLOW REGIONS (0) & (3)
C     IREGIN 4   FLOW REGIONS (1) & (4)
C     IREGIN 5   FLOW REGIONS (2) & (5)
C     IFORE      FLOW STATE IN FRONT OF THE SHOCK WAVE
C     IHIND      FLOW STATE BEHIND THE SHOCK WAVE
C
      MACH1 = DBLE(SMACH1)
      PRS1 = DBLE(SPRS1)
      TMP1 = DBLE(STMP1)
      PHI1 = DBLE(SPHI1)
      ICOUNT=0

15    ICOUNT=ICOUNT+1
C     DEFINE THE STATE OF FLOW
      IF(IREAL.EQ.2) GOTO 6
      GOTO (1,2,3,4,5),IREGIN
C     REGIONS (0) & (1)
1     IFORE=ISTAT0
      IHIND=ISTAT1
      GOTO 7
C     REGIONS (1) & (2)
2     IFORE=ISTAT1
      IHIND=ISTAT2
      GOTO 7
C     REGIONS (0) & (3)
3     IFORE=ISTAT0
      IHIND=ISTAT3
      GOTO 7
C     REGIONS (1) & (4)
4     IFORE=ISTAT1
      IHIND=ISTAT4
      GOTO 7
C     REGIONS (2) & (5)
5     IFORE=ISTAT2
      IHIND=ISTAT5
      GOTO 7
C     ALREADY DEFINED VIB. EQUILIBRIUM
6     IFORE=1
      IHIND=1
C
7     RR = 8.3201D3
      FACT11 = 1.0D-5
      IF(IC.EQ.2) FACT11 = FACT11*DCOS(PHI1)**2/1.5D0
      IF(DABS(PHI1-1.57079632).LT.1.0D-7) PHI1 = 1.5707963
      CALL GAS(PRS1,TMP1,GMM1,RHO1,H1,A1,MASS,IFORE)
      U1 = MACH1*A1
C
      C1 = RHO1*DTAN(PHI1)
      C2 = RHO1*U1*DSIN(PHI1)
      C3 = PRS1+RHO1*U1**2*DSIN(PHI1)**2
      C4 = H1+0.5*U1**2*DSIN(PHI1)**2
C
      CC = C3**2-2.0*C2**2*C4*(GMM1**2-1.0)/GMM1**2
      IF(CC.LE.0.0D0) CC = 0.0D0
      TRHO = (C3+DSQRT(CC))/(2.0*C4*(GMM1-1.0)/GMM1)
      TPRS = C3-C2**2/TRHO
      TTMP = TPRS/TRHO/RR*MASS
      TSTEP = 0.3*TTMP
      PSTEP = 0.2*TPRS
      K = 0
C
C  ---  START ITERATION  ---
C
   10 DO 20 I = 1,3
      DO 30 J = 1,2
      TP = TPRS+(I-2)*(2-J)*PSTEP
      TT = TTMP+(I-2)*(J-1)*TSTEP
      CALL GAS(TP,TT,TGMM,TRHO,TH,TA,MASS,IHIND)
      A3(I,J) = (C3-C2**2/TRHO-TP)/C3
      A4(I,J) = (C4-0.5*C2**2/TRHO**2-TH)/C4
   30 CONTINUE
   20 CONTINUE
C
      IF(DABS(A3(2,1)).LT.FACT11.AND.DABS(A4(2,1)).LT.FACT11) GO TO 40
      IF(K.GE.25) GO TO 50
C
      B1 = (A3(3,1)-A3(1,1))/PSTEP/2.0
      B2 = (A4(3,1)-A4(1,1))/PSTEP/2.0
      A1 = (A3(3,2)-A3(1,2))/TSTEP/2.0
      A2 = (A4(3,2)-A4(1,2))/TSTEP/2.0
      BB = (A1*B2-A2*B1)
      PS = (A1*A4(2,1)-A2*A3(2,1))/BB
      TS = (B1*A4(2,1)-B2*A3(2,1))/BB
      IF(DABS(PS/TPRS).GT.0.2) PS = TPRS*0.2*PS/DABS(PS)
      IF(DABS(TS/TTMP).GT.0.2) TS = TTMP*0.2*TS/DABS(TS)
      TPRS = TPRS-PS
      TTMP = TTMP+TS
      PSTEP = 0.3*DABS(PS)
      TSTEP = 0.3*DABS(TS)
      K = K+1
      GO TO 10
```

```
C
   50 ILL = 999
      RETURN
C
   40 ILL = 0
      PRS2 = TPRS
      TMP2 = TTMP
      CALL GAS(PRS2,TMP2,GMM2,RHO2,H2,A2,MASS,IHIND)
      PHI2 = DATAN(C1/RHO2)
      IF(C1.LT.0.0) PHI2 = PHI2+3.14159265359
      U2 = C2/RHO2/DSIN(PHI2)
      MACH2 = U2/A2
C     IP = 1 , THERMODYN. STATES ARE AS GIVEN
C     IP = 2 , THERMODYN. STATES ARE TO BE DETERMINED BY THE PROGRAM
      IF(ICOUNT.EQ.IP) GOTO 1050

C     DEFINE THE STATE OF THE FLOW REGION
      CALL VIB(IGAS,PRS2,TMP2,TAU)
      V2=U2*DSIN(PHI2)
      VRL=TAU*V2*1.D-06
      IF(IP.EQ.2.AND.VRL.GT.0.001) GOTO 1025

C     FOR VIB. EQUILIBRIUM
      IF(IREGIN.EQ.1) ISTAT1=1
      IF(IREGIN.EQ.2) ISTAT2=1
      IF(IREGIN.EQ.3) ISTAT3=1
      IF(IREGIN.EQ.4) ISTAT4=1
      IF(IREGIN.EQ.5) ISTAT5=1
      GOTO 15

C     RESET ISTATE IF NOT IN VIB. EQUILIBRIUM
1025  IF(IREGIN.EQ.1) ISTAT1=0
      IF(IREGIN.EQ.2) ISTAT2=0
      IF(IREGIN.EQ.3) ISTAT3=0
      IF(IREGIN.EQ.4) ISTAT4=0
      IF(IREGIN.EQ.5) ISTAT5=0
C
1050  SMACH2 = SNGL(MACH2)
      SPRS2 = SNGL(PRS2)
      STMP2 = SNGL(TMP2)
      SPHI2 = SNGL(PHI2)
      RETURN
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  TRPL1  ***
C     ------------------------------------------------------------------

      SUBROUTINE TRPL1(THETAW,MACHS,PRS0,TMP0,CHI,PHI1,MACH2,MACHK,PHIK,
     1THEMIN,DELTA,PHI3,CHIP,IC,ILL)

      REAL MACHS,MACH0,MACH1,MACH2,MACH3,MACHK
      DIMENSION AP(3,2),AT(3,2),AM(3),APHI(3,3)
      DOUBLE PRECISION DPRS(3,2),DTMP(3,2),DRHO0,DRHO1,DUM,DPRS0,DTMP0,D
     1A0,DA2
      COMMON /C1/SLIP,EPSLN
      COMMON /ST/ISTAT0,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5
C
      FACT1 = 1.0E-4
      FACT2 = 1.0E-4
      Q2 = 0.017453293
C
C  ---  SET INITIAL VALUE FOR CHI AND PHI1  ---
C
      CALL INTL(PRS0,TMP0,THETAW,MACHS,TCHI,CSTEP,TPHI1,PSTEP)
      TCHI = TCHI+EPSLN
      TPHI1 = TPHI1-EPSLN
      IF(TCHI-CSTEP.LT.THEMIN-THETAW) TCHI = THEMIN-THETAW+CSTEP*1.1
      TCHIF = TCHI
      MACH0 = MACHS/SIN(90.0*Q2-THETAW-TCHI+CSTEP)
      CALL SVFS(MACH0,PRS0,TMP0,90.0*Q2-THETAW-TCHI+CSTEP,MACH1,PRS1,TMP
     11,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 105
      IF(MACH1*SIN(TPHI1-PSTEP).LT.1.0) TPHI1 = ASIN(1.0/MACH1)+1.1*PST
     1EP
      TPHI1F = TPHI1
      K = 0
C
C  ---  START ITERATION  ---
C
   10 IF(TCHI-CSTEP.GT.THEMIN-THETAW+0.02*Q2.AND.TCHI-CSTEP.GT.0.0) GO T
     1O 11
      CSTEP = 0.3*(TCHIF-AMAX1(THEMIN-THETAW+0.02*Q2,0.0))
      TCHI = 1.2*CSTEP+AMAX1(THEMIN-THETAW+0.02*Q2,0.0)
      TCHIF = TCHI
   11 MACH0 = MACHS/SIN(90.0*Q2-THETAW-TCHI+CSTEP)
      CALL SVFS(MACH0,PRS0,TMP0,90.0*Q2-THETAW-TCHI+CSTEP,MACH1,PRS1,TMP
     11,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 104
      IF(TPHI1.GT.90.0*Q2) GO TO 12
      IF(MACH1*SIN(TPHI1-PSTEP).GT.1.0) GO TO 14
      PSTEP = 0.4*ABS(TPHI1F-ASIN(1.0/MACH1))
      TPHI1 = ASIN(1.0/MACH1)+PSTEP*1.1
      TPHI1F = TPHI1
      GO TO 14
   12 IF(TPHI1+PSTEP.GT.180.0*Q2-PHI01) TPHI1 = 180.0*Q2-PHI01-PSTEP*1.1
      IF(MACH1*SIN(TPHI1+PSTEP).GT.1.0) GO TO 14
      PSTEP = 0.4*ABS(180.0*Q2-ASIN(1.0/MACH1)-TPHI1F)
      TPHI1 = 180.0*Q2-ASIN(1.0/MACH1)-PSTEP*1.1
   14 IF(TPHI1.GT.124.0*Q2) TPHI1 = 100.0*Q2
      TPHI1F = TPHI1
      DO 20 I = 1,3
      DO 30 J = 1,2
      IF(I*J.EQ.4) GO TO 30
      TC = TCHI+(I-2)*(2-J)*CSTEP
      TP = TPHI1+(I-2)*(J-1)*PSTEP
      PHI0 = 90.0*Q2-(THETAW+TC)
      MACH0 = MACHS/SIN(PHI0)
      PHI3 = 90.0*Q2-TC+EPSLN
      CALL SVFS(MACH0,PRS0,TMP0,PHI0,MACH1,PRS1,TMP1,PHI01,2,ILL,1)
      IF(ILL.NE.0) GO TO 101
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      CALL SVFS(MACH1,PRS1,TMP1,TP,MACH2,PRS2,TMP2,PHI12,2,ILL,3)
      IF(ILL.NE.0) GO TO 102
      CALL SVFS(MACH0,PRS0,TMP0,PHI3,MACH3,PRS3,TMP3,PHI33,2,ILL,3)
      IF(ILL.NE.0) GO TO 103
      AP(I,J) = (PRS3-PRS2)/PRS2
      AT(I,J) = (PHI3-PHI33)-(PHI0-PHI01)+(TP-PHI12)-SLIP
      AM(I) = MACH2
      DPRS0 = PRS0
      DPRS(I,1) = PRS1
      DPRS(I,2) = PRS2
      DTMP0 = TMP0
      DTMP(I,1) = TMP1
      DTMP(I,2) = TMP2
      APHI(I,1) = PHI0
      APHI(I,2) = PHI01
      APHI(I,3) = PHI12
   30 CONTINUE
   20 CONTINUE
C
      IF(ABS(AP(2,1)).LT.FACT1.AND.ABS(AT(2,1)).LT.FACT2) GO TO 40
      IF(K.GT.25) GO TO 50
C
      IF((AP(3,2)-AP(1,2))*(AT(3,2)-AT(1,2)).EQ.0.0) GO TO 42
      B1 = (AP(3,1)-AP(1,1))/CSTEP/2.0
      B2 = (AT(3,1)-AT(1,1))/CSTEP/2.0
      A1 = (AP(3,2)-AP(1,2))/PSTEP/2.0
      A2 = (AT(3,2)-AT(1,2))/PSTEP/2.0
      BB = A1*B2-A2*B1
      PP = (B1*AT(2,1)-B2*AP(2,1))/BB
      IF(ABS(PP).GT.20.0*Q2) PP = 20.0*Q2*PP/ABS(PP)
      TPHI1F = TPHI1
      TPHI1 = TPHI1+PP
      PSTEP = 0.3*ABS(PP)
      CC = (A1*AT(2,1)-A2*AP(2,1))/BB
      IF(ABS(CC).GT.10.0*Q2) CC = 5.0*Q2*CC/ABS(CC)
      TCHIF = TCHI
      TCHI = TCHI-CC
      CSTEP = ABS(CC)
      GO TO 41
   42 TCHIF = TCHI
      TCHI = TCHI+2.0*CSTEP*AT(2,1)/(AT(1,1)-AT(3,1))
      CSTEP = 0.3*ABS(2.0*CSTEP*AT(2,1)/(AT(1,1)-AT(3,1)))
   41 K = K+1
      GO TO 10
C
   50 ILL = 999
      RETURN
C
   40 ILL = 0
      CHI = TCHI
      PHI1 = TPHI1
      DELTA = 180.0*Q2-(APHI(2,2)+TPHI1)
      MACH2 = AM(2)
      IF(IC.EQ.1) RETURN
      CALL GAS(DPRS0,DTMP0,DUM,DRHO0,DUM,DA0,DUM,ISTAT0)
      CALL GAS(DPRS(2,1),DTMP(2,1),DUM,DRHO1,DUM,DUM,DUM,ISTAT1)
      CALL GAS(DPRS(2,2),DTMP(2,2),DUM,DUM,DUM,DA2,DUM,ISTAT2)
      RHO0 = DRHO0
      RHO1 = DRHO1
      A0 = DA0
      A2 = DA2
      VKT = RHO0/RHO1/SIN(TPHI1+APHI(2,2))*MACH2*A0
      V2T = MACH2*A2
      MACHE = MACH2*SQRT(1.0+(VKT/V2T)**2-2.0*VKT/V2T*COS(APHI(2,2)
     1+TPHI1+APHI(2,3)))
      PHIK = ATAN((1.0-RHO0/RHO1)/(COTAN(APHI(2,2)+TPHI1)+RHO0/RHO1
     1TAN(TPHI1+APHI(2,3))))
      CHIP = 90.*Q2-THETAW-PHIK
C     WRITE(6,*)THETAW,CHI,PHIK,CHIP
      RETURN
C
  101 WRITE(6,601)
  601 FORMAT(1H ,'(STOPPED AT TRPLI 101)')
      GO TO 1000
  102 WRITE(6,602)
  602 FORMAT(1H ,'(STOPPED AT TRPLI 102)')
      GO TO 1000
  103 WRITE(6,603)
  603 FORMAT(1H ,'(STOPPED AT TRPLI 103)')
      GO TO 1000
  104 WRITE(6,604)
  604 FORMAT(1H ,'(STOPPED AT TRPLI 104)')
      GO TO 1000
  105 WRITE(6,605)
  605 FORMAT(1H ,'(STOPPED AT TRPLI 105)')
 1000 ILL = 999
      RETURN
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  TRPL2  ***
C     ------------------------------------------------------------------


      SUBROUTINE TRPL2(MACH1,PRS1,TMP1,PHI1,PHI01,THEWPP)

      DOUBLE PRECISION DP2P,DP4,DP5,DT2P,DT4,DT5,GMM1,GMM2P,GMM4,
     .GMM5,DR2P,DR4,DR5,DA1,DA2P,DA4,DA5,DPR,DTM,AS
      REAL MACH1,MACH1P,MACH2P,MACH4,MACH5,MA(3)
      DIMENSION AP(3,2),AT(3,2),AM(3),PR(3),TM(3),PH(3),TH(3),
     .IST(3),VRL(3)
      COMMON IREAL,IGAS,G0,ALPHA,BETA
      COMMON /ST/ISTAT0,ISTAT1,ISTAT2,ISTAT3,ISTAT4,ISTAT5
      COMMON /GUESS/GT2,GT4

      FACT1=1.0E-4
      FACT2=1.0E-4
      Q1=13.6*9.806
      Q2=0.017453293

      PHI1P=PHI1+PHI01
      MACH1P=MACH1*(1.+SIN(PHI01)*SIN(PHI01)/(SIN(PHI1P)*SIN(PHI1P))
```

```
     .-2.*SIN(PHI01)*COS(PHI1)/SIN(PHI1P))**0.5
      CALL SVFS(MACH1P,PRS1,TMP1,PHI1P,MACH2P,PRS2P,TMP2P,PHI12P,2,
     .ILL,2)
      WRITE(6,511)MACH1P
  511 FORMAT(/' MACH1P = ',F10.4)
      IF(ILL.NE.0) GO TO 101
C     NOT DMR CASE
      IF(MACH2P.LT.1.0) GOTO 1000

C     SET INITIAL VALUES FOR PHI4 AND PHI2
      TPHI4=GT4*Q2
      P4STEP=2.*Q2
      TPHI2=GT2*Q2
      P2STEP=2.*Q2

      IF(MACH2P*SIN(TPHI2-P2STEP).LT.1.0) TPHI2=ASIN(1.0/MACH2P)
     .+1.1*P2STEP
      TPHI2F=TPHI2
      TPHI4F=TPHI4
      K=0

C     START ITERATION
   10 IF(TPHI4+P4STEP.GT.(PHI1P-5.*Q2).AND.TPHI4+P4STEP.GT.0.0)GOTO 11
      P4STEP=1.1*TPHI4F
      TPHI4=1.2*TPHI4+P4STEP
      TPHI4F=TPHI4
   11 CALL SVFS(MACH1P,PRS1,TMP1,TPHI4,MACH4,PRS4,TMP4,PHI14,2,ILL,4)
      IF(ILL.NE.0) GO TO 102
      IF(TPHI2.GT.90.*Q2) GO TO 12
      IF(MACH2P*SIN(TPHI2-P2STEP).GT.1.0) GO TO 14
      P2STEP=0.4*ABS(TPHI2F-ASIN(1.0/MACH1P))
      TPHI2=ASIN(1.0/MACH1P)+P2STEP*1.1
      TPHI2F=TPHI2
      GO TO 14
   12 IF(TPHI2+P2STEP.GT.180.*Q2-PHI12P) TPHI2=180.*Q2-PHI12P-P2STEP*1.1
      IF(MACH1P*SIN(TPHI2+P2STEP).GT.1.0) GO TO 14
      P2STEP=0.4*ABS(180.*Q2-ASIN(1.0/MACH1P)-TPHI2F)
      TPHI2=180.*Q2-ASIN(1.0/MACH1P)-P2STEP*1.1
   14 IF(TPHI2.GT.179.*Q2) TPHI2=175.*Q2
      TPHI2F=TPHI2
      DO 20 I=1,3
      DO 30 J=1,2
      IF(I*J.EQ.4) GO TO 30
      TP4=TPHI4+(I-2)*(2-J)*P4STEP
      TP2=TPHI2+(I-2)*(J-1)*P2STEP
      PHI4=TP4
      PHI2=TP2
      CALL SVFS(MACH2P,PRS2P,TMP2P,PHI2,MACH5,PRS5,TMP5,PHI25,2,ILL,5)
      IF(ILL.NE.0) GO TO 103
      CALL SVFS(MACH1P,PRS1,TMP1,PHI4,MACH4,PRS4,TMP4,PHI14,2,ILL,4)
      IF(ILL.NE.0) GO TO 104
      AP(I,J)=(PRS4-PRS5)/PRS5
      AT(I,J)=(PHI4-PHI14)-(PHI1P-PHI12P)+(TP2-PHI25)
      AM(I)=MACH5
      IF(I.NE.2) GOTO 30
      IF(J.NE.1)GOTO 30
      AM4=MACH4
      AP4=PRS4
      AT4=TMP4
      AM5=MACH5
      AP5=PRS5
      AT5=TMP5
      P25=PHI25
      P14=PHI14
   30 CONTINUE
   20 CONTINUE

      IF(ABS(AP(2,1)).LT.FACT1.AND.ABS(AT(2,1)).LT.FACT2) GO TO 40
      IF(K.GT.25) GO TO 50

      IF((AP(3,2)-AP(1,2))*(AT(3,2)-AT(1,2)).EQ.0.0) GO TO 42
      B1=(AP(3,1)-AP(1,1))/P4STEP/2.0
      B2=(AT(3,1)-AT(1,1))/P4STEP/2.0
      A1=(AP(3,2)-AP(1,2))/P2STEP/2.0
      A2=(AT(3,2)-AT(1,2))/P2STEP/2.0
      BB=A1*B2-A2*B1
      PP=(B1*AT(2,1)-B2*AP(2,1))/BB
      IF(ABS(PP).GT.20.*Q2) PP=20.*Q2*PP/ABS(PP)
      TPHI2F=TPHI2
      TPHI2=TPHI2+PP
      P2STEP=0.3*ABS(PP)
      CC=(A1*AT(2,1)-A2*AP(2,1))/BB
      IF(ABS(CC).GT.10.*Q2) CC=5.*Q2*CC/ABS(CC)
      TPHI4F=TPHI4
      TPHI4=TPHI4-CC
      P4STEP=ABS(CC)
      GO TO 41
   42 TPHI4F=TPHI4
      TPHI4=TPHI4+2.*P4STEP*AT(2,1)/(AT(1,1)-AT(3,1))
      P4STEP=0.3*ABS(2.*P4STEP*AT(2,1)/(AT(1,1)-AT(3,1)))
   41 K=K+1
      GO TO 10

   50 ILL=999
      RETURN

   40 ILL=0
      PHI4=TPHI4
      PHI2=TPHI2
      MACH5=AM(2)
      P2P=PRS2P/Q1
      P4=AP4/Q1
      P5=AP5/Q1
      DP2P=PRS2P
      DP4=AP4
      DP5=AP5
      DT2P=TMP2P
      DT4=AT4
      DT5=AT5
      CALL GAS(DP2P,DT2P,GMM2P,DR2P,DUM,DA2P,DUM,ISTAT2)
      CALL GAS(DP4,DT4,GMM4,DR4,DUM,DA4,DUM,ISTAT4)
      CALL GAS(DP5,DT5,GMM5,DR5,DUM,DA5,DUM,ISTAT5)
```

```
      T2P=PHI1P-PHI12P
      T4=PHI4-P14
      T5=PHI2-P25
      DELTA=180.*Q2-(PHI01+PHI1)
      PSI=DELTA+PHI1P+PHI2-T2P-THEWPP-90.*Q2
      SIGMA=90.*Q2+THEWPP+PHI4-PHI1P-DELTA
      ETA=180.*Q2-(PHI2+PHI12P)
      XI=180.*Q2+(PHI1P-PHI4)
      WRITE(6,610)
      WRITE(6,619) ISTAT2,ISTAT4,ISTAT5
      WRITE(6,611)MACH2P,MACH4,MACH5
      WRITE(6,612)P2P,P4,P5
      WRITE(6,613)TMP2P,AT4,AT5
      WRITE(6,614)DR2P,DR4,DR5
      WRITE(6,618)DA2P,DA4,DA5
      WRITE(6,615)T2P/Q2,T4/Q2,T5/Q2
      WRITE(6,616)PHI1P/Q2,PHI4/Q2,PHI2/Q2
      WRITE(6,617)PSI/Q2,SIGMA/Q2,ETA/Q2,XI/Q2
      MA(1)=MACH2P
      MA(2)=MACH4
      MA(3)=MACH5
      PR(1)=PRS2P
      PR(2)=AP4
      PR(3)=AP5
      TM(1)=TMP2P
      TM(2)=AT4
      TM(3)=AT5
      PH(1)=PHI1P/Q2
      PH(2)=PHI4/Q2
      PH(3)=PHI2/Q2
      TH(1)=T2P/Q2
      TH(2)=T4/Q2
      TH(3)=T5/Q2
      IST(1)=ISTAT2
      IST(2)=ISTAT4
      IST(3)=ISTAT5
      DO 60 I=1,3
      CALL VIB(IGAS,PR(I),TM(I),TAU)
      DPR=PR(I)
      DTM=TM(I)
      CALL GAS(DPR,DTM,DUM,DUM,DUM,AS,DUM,IST(I))
      V2=MA(I)*AS*SIN((PH(I)-TH(I))*3.14159/180.)
      VRL(I)=TAU*V2*1.E-06*1000.
60    CONTINUE
      WRITE(6,621)(VRL(I),I=1,3)
      RETURN
C
101   WRITE(6,601)
601   FORMAT('STOPPED AT TRPL2 101')
      GO TO 1000
102   WRITE(6,602)
602   FORMAT('STOPPED AT TRPL2 102')
      GO TO 1000
103   WRITE(6,603)
603   FORMAT('STOPPED AT TRPL2 103')
      GO TO 1000
104   WRITE(6,604)
604   FORMAT('STOPPED AT TRPL2 104')
610   FORMAT(/5X,'SECOND TRIPLE POINT:'//10X,'** REGION **',9X,2H2',
     .10X,'4',11X,'5')
611   FORMAT(1H ,10X,'MACH',10X,3(F8.4,4X))
612   FORMAT(1H ,10X,'PRESSURE',5X,3(F10.2,2X))
613   FORMAT(1H ,10X,'TEMPERATURE',2X,3(F10.2,2X))
614   FORMAT(1H ,8X,'DENSITY (KG/M**3)',3(F10.7,2X))
615   FORMAT(1H ,10X,'THETA',10X,3(F7.3,5X))
616   FORMAT(1H ,10X,'PHI',12X,3(F7.3,5X))
617   FORMAT(/11X,'PSI = ',F7.2,3X,'SIGMA = ',F7.2,3X,'ETA = ',F7.3,
     .3X,'XI = ',F7.3)
618   FORMAT(1H ,10X,'SOUND SPEED',2X,3(F10.2,2X))
619   FORMAT(1H ,9X,'** STATE  **',9X,I1,11X,I1,11X,I1,/)
621   FORMAT(7X,'VIB. R.I.(MU) IN REGIONS 2, 4 & 5 = ',3(F10.4,2X))
1000  ILL=999

      RETURN
      END


C     ------------------------------------------------------------------
C                 ***  SUBROUTINE SUB-PROGRAM  VIB  ***
C     ------------------------------------------------------------------

      SUBROUTINE VIB(IGAS,PRS,TMP,TAU)

      IMPLICIT REAL*8(A-H,O-Z)
C     DEFINE THE STATE OF FLOW
      GOTO (100,200,300,400,500,600,700),IGAS
C     AIR (N2 IN AIR) REF. [WHITE & MILLIKAN]
  100 TAU=10.**(-213.5973*TMP**(-2./3.)+82.3374*TMP**(-1./3.)
     1-9.0463)*1.E+06/PRS*101325.
C     TAU=(2.9D-04*DEXP(126.*TMP**(-1./3.))
C    1+6.22D-05*DEXP(202.*TMP**(-1./3.)))*1./PRS*101325.
      RETURN
C     NITROGEN
  200 TAU=(6.22D-05*DEXP(202.*TMP**(-1./3.)))*1/PRS*101325.
      RETURN
C     ARGON
  300 TAU=9999.
      RETURN
C     CARBON DIOXIDE
  400 TAU=DEXP(36.5*TMP**(-1./3.)-3.9)*1./PRS*101325.
      RETURN
C     SULPHUR HEXAFLUORIDE (SF6)
  500 TAU=2.92D-03*DEXP(38.*TMP**(-1./3.))*1./PRS*101325.
      RETURN
C     GAMMA = 1.3333
  600 TAU=9999.
      RETURN
C     ONLY OXYGEN IS EXCITED IN AIR -- REF.[BLACKMAN , VINCENTI]
  700 TAU=2.92D-04*DEXP(126.*TMP**(-1./3.))/0.527*101325./PRS
      RETURN
      END
C     ******************************************************************
```

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1. Oblique-shock-wave reflections 2. Regular reflection 3. Mach reflection
4. Numerical and graphical solutions 5. Frozen and equilibrium flows

I. Hu, T. C. J., Shirouzu, M. II. UTIAS Report No. 283

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